SURFACE BYPASS AND COLLECTION SYSTEM
DEWATERING SYSTEM FIELD INVESTIGATION

DEWATERING
FUNCTIONAL DESIGN CRITERIA

CONTRACT No. DACW68-94-0008
DELIVERY ORDER No. 2

TASK ASSIGNMENT No. 6

FINAL

JULY 1995

PREPARED FOR
U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT

PREPARED BY
STONE & WEBSTER ENGINEERING CORPORATION
J.O. No. 05570.02

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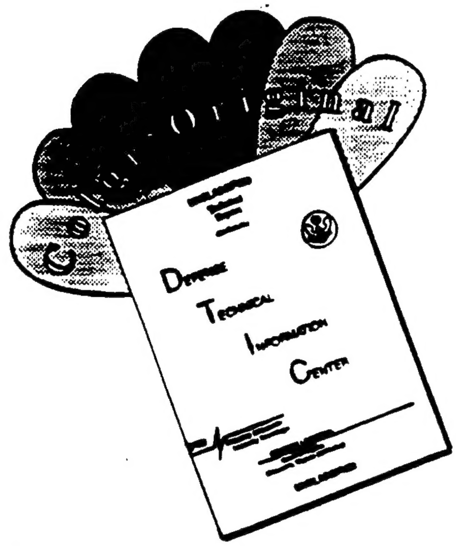

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USACE, WALLA WALLA DISTRICT

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Denver, Colorado

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1.0 INTRODUCTION

1.1 Overview

The U.S. Army Corps of Engineers (USACE) Walla Walla and Portland Districts have developed a program for surface bypass and collection system (SBCS) prototypes for improving survival of juvenile salmon migrating past Corps Lower Snake and Columbia Rivers hydroelectric projects. New surface bypass and collection systems that can safely bypass fish with considerably less spill than that currently used, could be designed to optimize fish passage while at the same time minimizing both dissolved gas related problems and lost power revenues.

Prototype SBCS designs (using existing/new concepts and utilizing fish behavior to accentuate system performance) are being identified, evaluated and tested. Results from ongoing baseline data collection and secondary studies at these and other projects will allow for rapid implementation of SBCS's at other Corps dams, if justified by prototype test results.

Water flowing into a surface bypass and collection system, located upstream of existing turbine intakes and/or spillways, will provide migrating juvenile fish with another passage route around the dam. It is hoped that a SBCS in the forebay will take advantage of the behavioral tendencies of juvenile fish to swim in the upper levels of the reservoir pool. Surface collector and bypass prototype designs, based on project specific fish behavior and river hydraulic characteristics, will be developed assuming the system must have the capabilities to either directly bypass fish past the dams for in-river migration or directing fish to conventional holding/loading facilities for transport by truck and barge to a location below Bonneville Dam on the Columbia River. SBCS's could be operated independently or in combination with the existing collection systems.

The USACE Walla Walla District (NPW) District is developing a juvenile fish SBCS prototype at Lower Granite Dam on the Lower Snake River, Washington State. Lower Granite Dam is prioritized because it is at the beginning of the river system, where it passes a large number of juvenile salmon, and because of concern for stocks listed as endangered under the Endangered Species Act. The NPW is currently preparing designs for the prototype collection structures that are to be constructed and in operation for slot testing in the spring of 1996. The dewatering system component of the SBCS prototype at Lower Granite Dam is scheduled to be in operation in the spring of 1997. Stone & Webster Engineering Corporation has been retained to assist the NPW District in the preparation of designs for the Lower Granite SBCS prototype dewatering system.

1.2 Purpose

The purposes of this study were: 1) perform full investigations of the Lower Snake and Columbia River project's existing juvenile fish facilities to determine baseline design, operational and maintenance parameters; 2) identify dewatering systems that may apply to the SBCS; and 3) develop design criteria for dewatering system alternatives. The scope of work performed for

this study was as follows:

- **Task 1** - Develop a questionnaire that focuses on the dewatering systems being used at the Snake and Columbia River projects with the intent to obtain information from fish facility designers and operators on dewatering system design, operation and maintenance and reliability concerns.

- **Task 2** - Inspect existing NPW projects fish collection and bypass facilities in an unwatered state and talk to the operators about design, operation and maintenance and reliability concerns.

- **Task 3** - Prepare a written summary of the A/E's observations, results of the Task 1 questionnaire responses and Task 2 site inspections. The summary should include a description of each project, methods employed for collection, bypassing and dewatering, maintenance and operational concerns.

- **Task 4** - Perform a literature search of the latest information relating to dewatering system research and development. The search should involve: contacting Pacific Northwest Fish Agencies, Utilities, other A/E firms, Canadian projects and the Corps of Engineers Portland District; and researching professional technical literature and technical society resources.

- **Task 5** - Inspect existing NPW projects fish collection and bypass facilities in an operational state and talk to the operators about design, operation and maintenance and reliability concerns. Inspect non-NPW projects fish collection and bypass facilities in an operational state to identify what others are using for fish protection.

- **Task 6** - Prepare a Functional Design Criteria (FDC) for dewatering systems which will: identify dewatering systems that may have application in the surface bypass and collection system and develop a database of information such that depending upon the specific application, a dewatering system can be identified from the FDC that would be suitable for that application.

1.3 Authorization

This study was authorized by Delivery Order No. 2, Contract No. DACW68-94-D-0008 between Stone & Webster Engineering Corporation (SWEC) and the U.S. Army Corps of Engineers (USACE) Walla Walla District (NPW). The USACE delivery order was issued on February 24, 1995 and modified on March 20, 1995.

2.0 PROJECT DESCRIPTIONS AND FIELD INVESTIGATION FINDINGS

2.1 Lower Granite Lock and Dam

General Project Description

Lower Granite Lock and Dam is located 37 river miles upstream of Little Goose Lock and Dam at Snake River mile 107 near Pullman, Washington. The dam crest is approximately 3,200 feet long consisting of a fish ladder on the left abutment, a 656-foot long powerhouse, a 512-foot long gated spillway, an 86-foot wide navigation lock, and an embankment section that extends from the navigation lock to the right abutment. The powerhouse contains six generators with total rated generating capacity of 810 megawatts (MW).

Lower Granite Lake is impounded by the dam extending 39 miles upstream with a surface area of 8,900 acres. The normal operating headwater pool varies between elevation 733 feet (minimum) and elevation 738 feet (maximum). The normal operating tailwater pool varies between elevation 633 feet (minimum) and elevation 645 feet (maximum). Average Snake River flow at Lower Granite Lock and Dam is about 50,000 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Lower Granite is unique since it was the only facility on the Lower Snake River to incorporate juvenile fish passage into the design. The original design incorporated a gatewell upstream of the collection channel for the submerged traveling screens. Orifices were oriented to pass fish from the upstream gatewell to the downstream collection channel. The submerged traveling screens are currently used in the gatewell downstream of the collection channel which was found to provide higher fish guidance efficiency. The upstream gatewells are being fitted with plugs for the '95 season.

Lower Granite has a trashboom in the forebay which extends from the North end of the powerhouse diagonally upstream to the South bank. The trashboom routes surface trash to the spillway area.

Juvenile fish approach the dam at various depths in the forebay, they follow the flow down into the turbine intakes and are diverted up into the gatewells by submerged screens. Juvenile fish entering the gatewell are discharged to the collection channel through tube-type orifices.

The collection channel runs the full length of the powerhouse from north to south. The collection channel transitions to a flume which routes the fish and water to a vertical chamber. The vertical chamber transitions into a pressurized conduit which is routed underground for approximately 1/4 mile and upwells at the dewatering screens directly upstream of the holding facilities. The primary dewatering screens reduce the flow from 200 - 250 cfs to 30 - 40 cfs.

The pressurized transportation conduit from the collection channel to the dewatering facilities results in reported increased stress levels on fish. Although mortality is not substantially higher at Lower Granite, stress appears to be greater, probably as a result of pressure changes and disorientation.

Dewatering Systems

Primary dewatering is through the floor dewatering screen immediately downstream of the upwell. The rectangular floor screen section is made up of steel grating covered with wire mesh. The wire mesh is 8x8 (8 wires per inch each direction) stainless steel square mesh wire with a gross area of 256 square feet. Design flows through the dewatering screens range up to 210 cfs.

Secondary dewatering occurs immediately downstream of the primary dewatering system. The rectangular floor screen section is made up of 82-inch long by 10 feet wide, 1/8-inch thick perforated plate with staggered 1/4-inch holes on 3/8-inch centers. Flow in controlled by 15 gates located 1.0 foot below the perforated plate. Secondary dewatering is used to more closely regulate the flow entering the separator.

Trash is a concern at the project since it clogs orifices and dewatering screens. Debris commonly consists of sticks, algae, leaves and wheat chaff. Dewatering screens typically consist of wire mesh and perforated plate and are highly susceptible to clogging by leaves and wheat chaff. Debris is removed from the dewatering screens by hand.

Emergency Fish Bypass System

The emergency fish bypass system is incorporated in the upwell to the dewatering system. The system bypasses fish in the upwell by means of a 5.5-foot diameter pipe controlled by a slide gate. The slide gate opening transitions to a 5.5-foot diameter pipe, then transitions to a 3.5-foot diameter pipe and is routed to the river. The slide gate is opened to route juvenile fish into the river in the event that either the dewatering system or the holding facilities are inoperable.

Fish Transportation System

Fish and transportation water leaving the collection channel transitions to a flume which routes the fish and water to a 6.0-foot by 15.0-foot vertical chamber. The vertical chamber transitions into a 42-inch diameter pressurized conduit. The conduit drops at a slope of 34% for approximately 110 feet and then drops at a slope of 20% for about 80 feet. It then runs approximately 1/4 mile underground and upwells at the dewatering screens directly upstream of the holding facilities.

Site Visit Observations and Findings

The following site visit observations and findings are based on SWEC's observations while visiting the site and interviews with project personnel. The magnitude of concern made in the following comments are subjective and are provided to give additional insight into system design and operation.

Off-Line Findings, Problems and Concerns with Current Systems

- Current dewatering screens are wire mesh and perforated screen. Screen lengths are short for amount of flow, impingement velocities may be too high.

On-Line Findings, Problems and Concerns with Current Systems

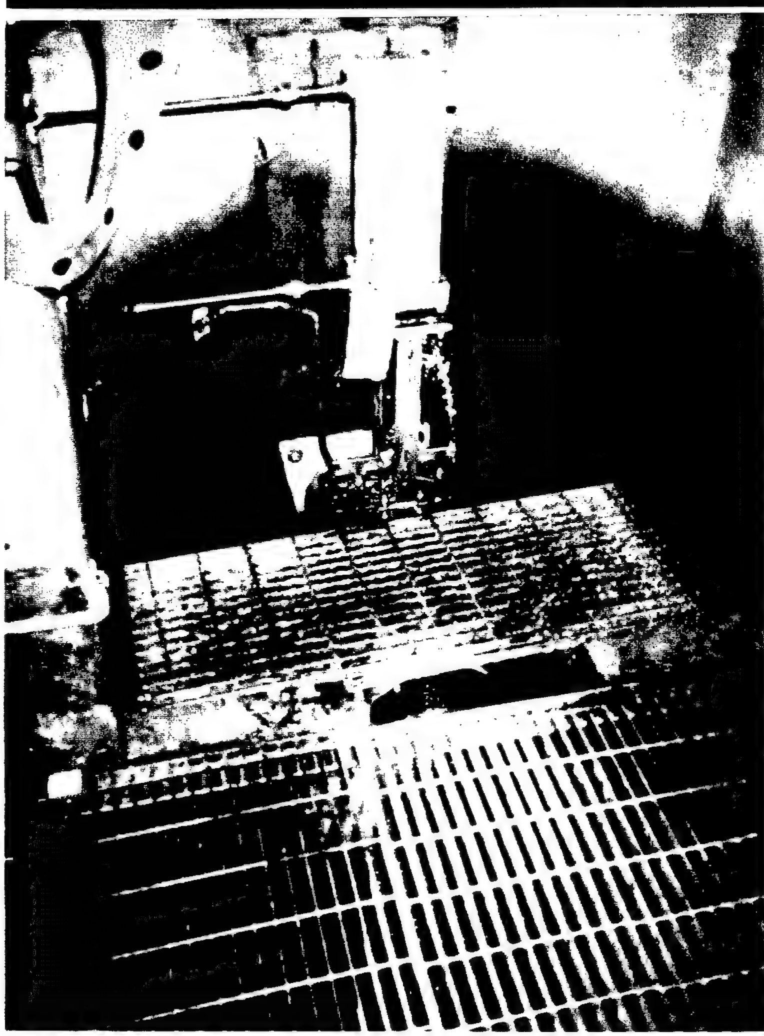
- The dewatering system operated smoothly with no reported maintenance problems.

Attributes and General Comments with the Current Systems

- Overall system works well, maintenance items are labor intensive.

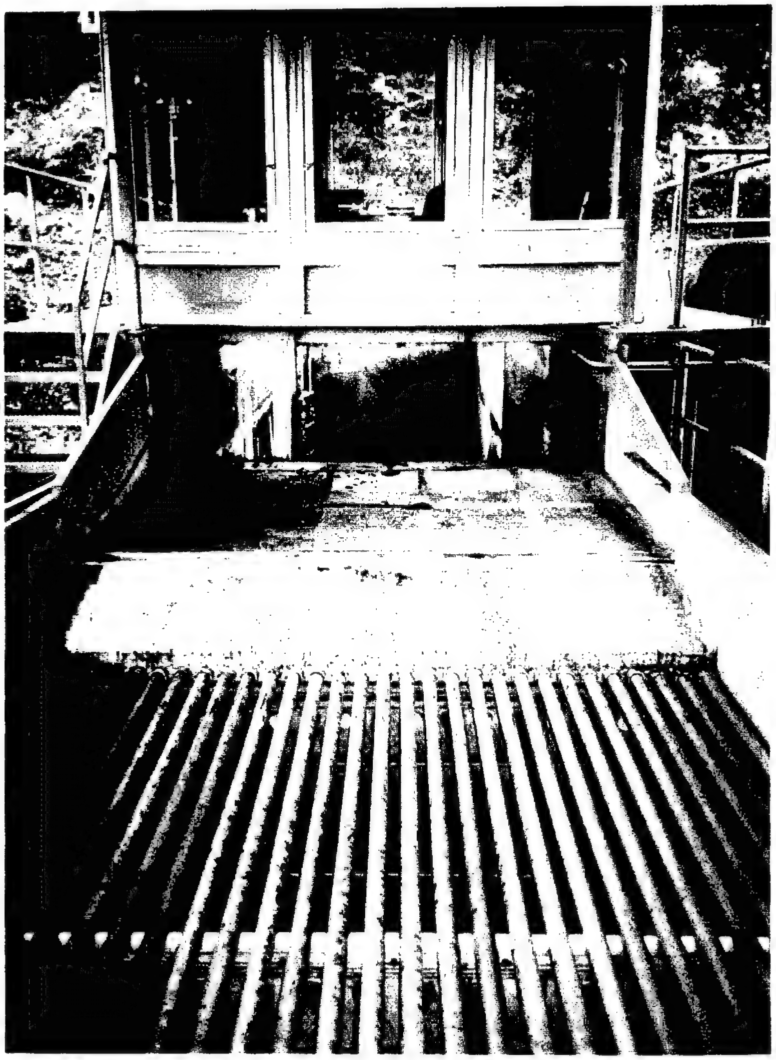
LOWER GRANITE LOCK AND DAM
Lower Snake River - Washington

Floating trash boom extending from left bank to first spillway bay. Powerhouse to left of trash boom.



Knife gate and operator to control gatewell orifices.

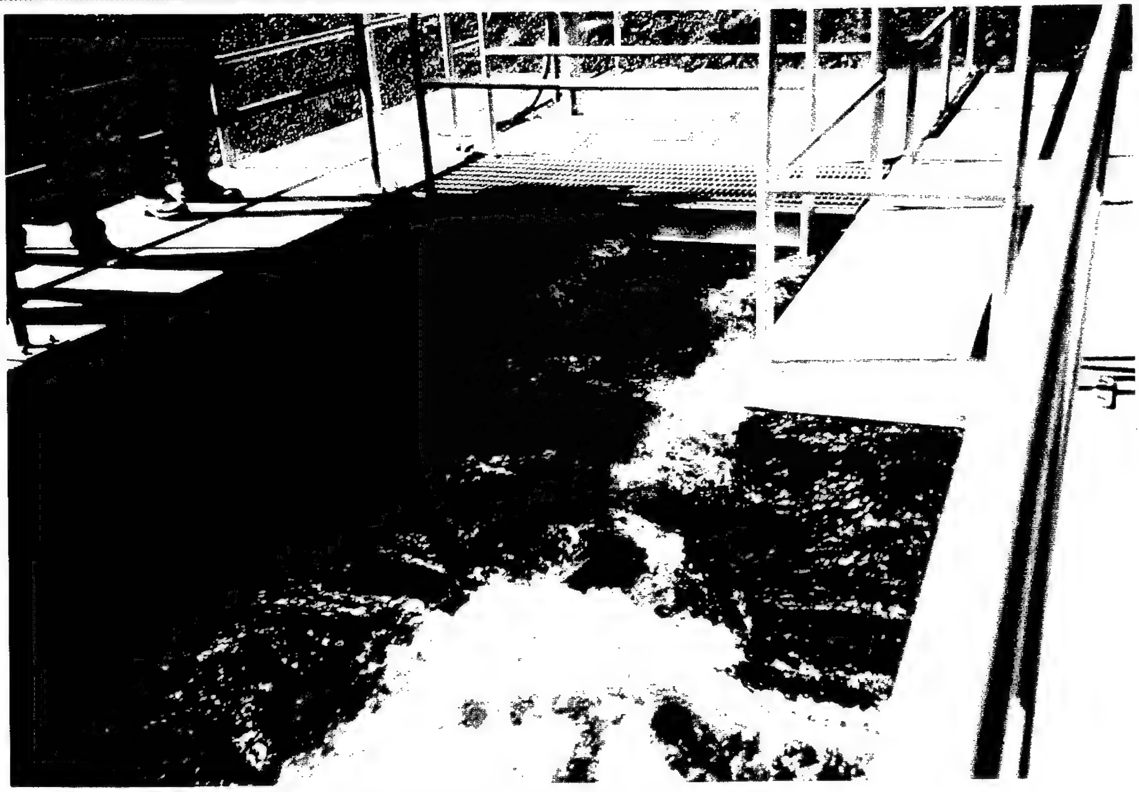
LOWER GRANITE LOCK AND DAM
Lower Snake River - Washington



Upwell from underground fish transportation conduit (pressurized) behind operator booth. Floor screen (wire mesh) below operator booth with fish sorting facilities in foreground. Emergency bypass sluice gate on sidewall of upwell in background.

Primary dewatering in background with wire mesh over steel grating. Secondary dewatering in foreground with perforated plate.

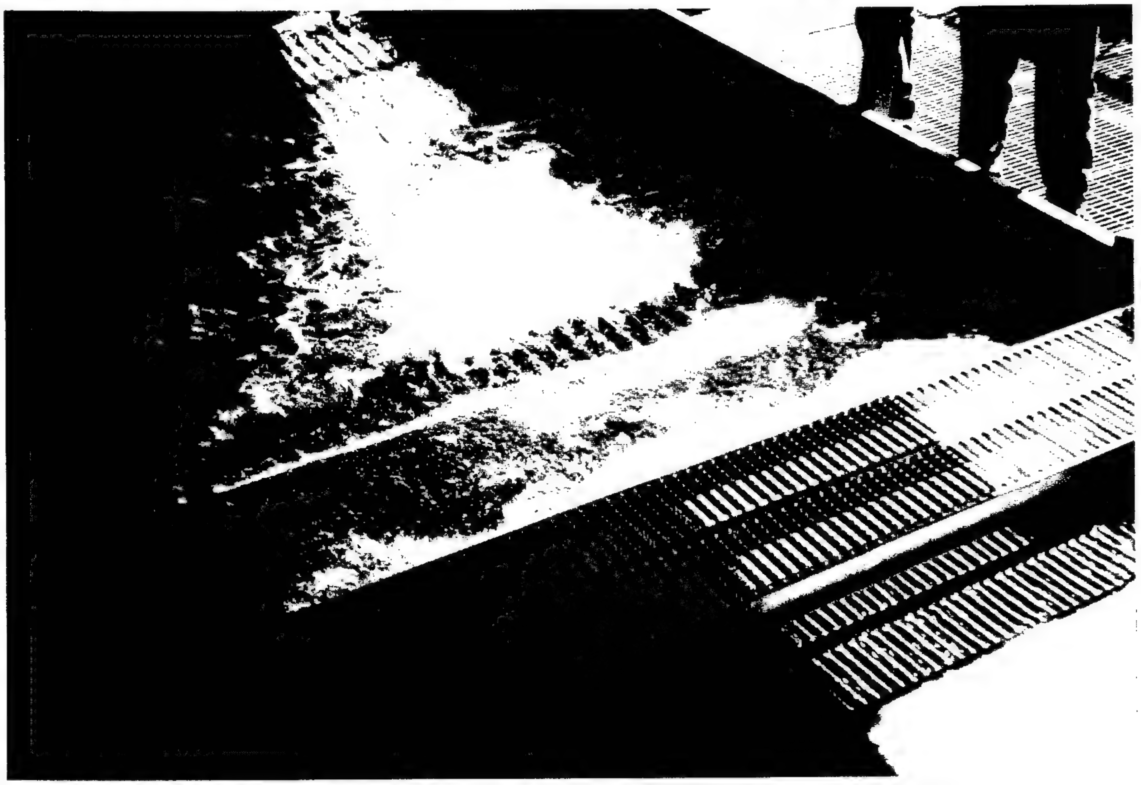
LOWER GRANITE LOCK AND DAM
Lower Snake River - Washington



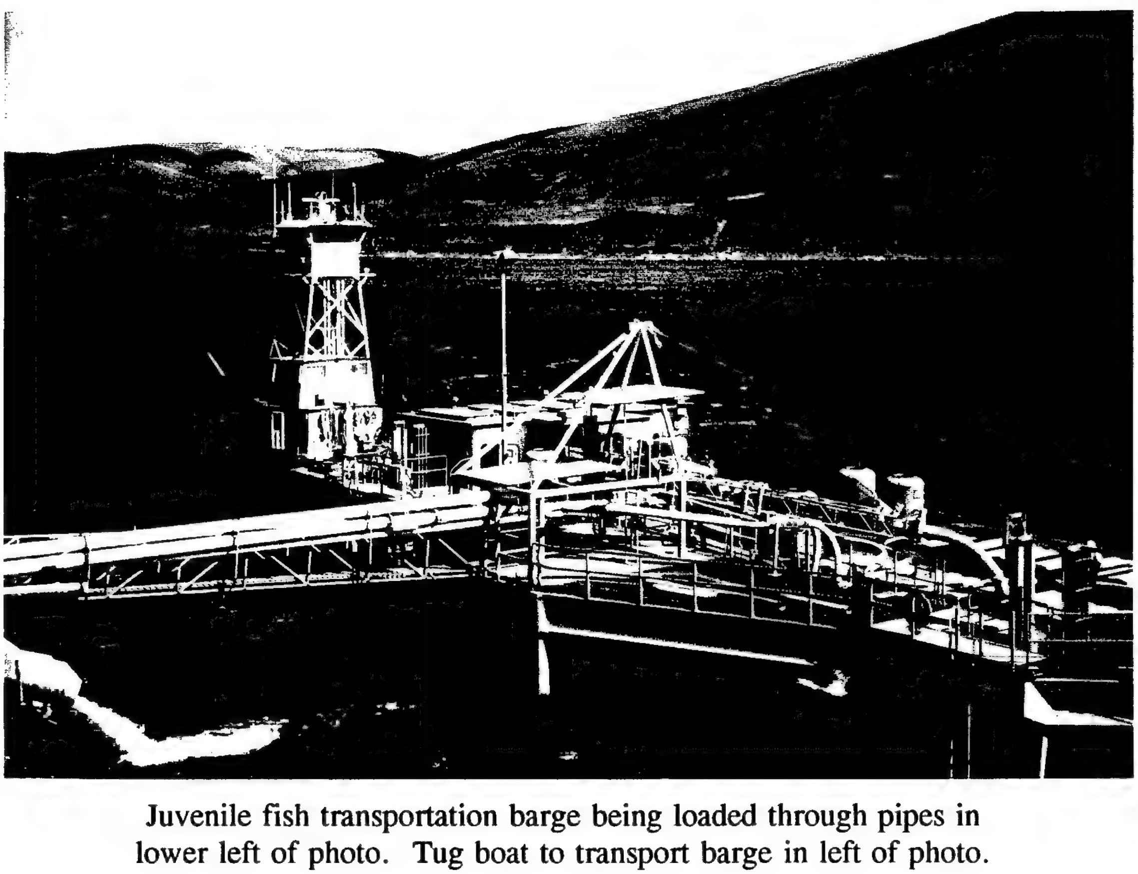
View of upwell discharge with minor surging.

Upstream view of bypass discharge from upwell, passing through primary and secondary dewatering systems, and entering fish separator in lower portion of photo.

LOWER GRANITE LOCK AND DAM
Lower Snake River - Washington



Bypass discharge entering fish separator after passing over secondary dewatering screens (lower right).



Juvenile fish transportation barge being loaded through pipes in lower left of photo. Tug boat to transport barge in left of photo.

2.2 Little Goose Lock and Dam

General Project Description

Little Goose Lock and Dam is located 28 river miles upstream of Lower Monumental Lock and Dam at Snake River mile 70 near Starbuck, Washington. The dam crest is approximately 2,655 feet in length consisting of an 84-foot wide navigation lock on the left abutment, a fish ladder, a 656-foot long powerhouse, a 512-foot long gated spillway, and an embankment section that extends from the spillway to the right abutment. The powerhouse contains six generators with a total rated generating capacity of 810 megawatts (MW).

Lake Bryan is impounded by the dam extending 37 miles upstream with a surface area of 10,025 acres. The normal operating headwater pool varies between elevation 633 feet (minimum) and elevation 638 feet (maximum). The normal operating tailwater pool varies between elevation 537 feet (minimum) and elevation 544 feet (maximum). Average Snake River flow at Little Goose Lock and Dam is about 50,000 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Juvenile fish approach the dam at various depths in the forebay, they follow the flow down into the turbine intakes and are diverted up into the gatewells by submerged screens. Juvenile fish entering the gatewell are discharged to the collection channel through tube-type orifices.

The collection channel runs the full length of the powerhouse from North to South. The collection channel transitions to a flume that routes the fish and water out the south end of the powerhouse to the primary dewatering system. The primary dewatering screens reduce the flow from 165 - 250 cfs to 35 - 40 cfs. The reduced flow enters a smooth transportation flume to a secondary side dewatering system which closely regulates the flow entering the corrugated transportation flume. The corrugated transportation flume is carried on towers to the holding facilities and the river.

No mortality or descaling problems have been attributed directly to the collection/dewatering facilities.

Dewatering Systems

Primary dewatering is through the floor dewatering screen. The floor screen is divided into nine sections; the first rectangular section is 9.5 feet long by 6 feet wide, the next 7 rectangular sections are 10 feet long by 6 feet wide and the last (downstream) section is a trapezoidal section 10 feet long transitioning from 6 feet wide to 3 feet wide. Design flows through the floor screens range up to 210 cfs.

The amount of water discharging through the primary dewatering screen and the water level in the main channel are regulated by a control weir system. The control weir section consists of:

a baffle arrangement to provide uniform flow through the screens, 9 - two foot high by nine foot long discharge orifices that route flows into a 90 foot long vertical chamber and 9 - four foot long by 4.5 foot tall automatic weirs that direct flow into a 90 foot long by 6 foot wide side chamber. The side chamber floor slopes to a drain pipe system consisting of a 6 foot square by 20 foot deep vertical chamber transitioning to a 42 inch diameter pipe that connects to an existing 30 inch diameter transportation conduit. The 30 inch diameter conduit supplies water to the holding facilities (raceways). A 90 foot long overflow weir located adjacent to the dewatering screen is set 1.5 feet below the top of the outside walls and prevents the flows from overtopping the structure.

Secondary dewatering occurs in the smooth flume section immediately downstream of the primary dewatering system. Secondary dewatering uses perforated plates on the side walls. Weirs directly behind the plates control and regulate the flow entering the corrugated flume.

Trash is a concern at the project since it clogs orifices and dewatering screens. Debris commonly consists of sticks, tumbleweeds and leaves. Dewatering screens which typically use wedge-wire screen with 1.75 mm bars spaced 2 mm apart and are highly susceptible to clogging by leaves. Debris is removed by brushes that travel the screen length from upstream to downstream. Debris usually ends up in the raceways and must be removed and disposed of manually.

The dewatering screen cleaning system utilizes two angle iron cross members attached to a roller chain, one behind the other. The lead cross member has two brushes approximately two feet in length with about one foot clear between them. The trailing cross member has the same brush arrangement, but the brushes are offset to cover the leading brush's clear space. The roller chain is driven to clean the screens from upstream to downstream. Each of the three rectangular screen sections have an independent roller chain cleaning system. The screen sections are cleaned in order from upstream to downstream. The trapezoidal section is cleaned by hand.

Emergency Fish Bypass System

Two emergency fish bypass systems are incorporated to route juvenile fish directly into the river in the event that either the primary dewatering screens or the transportation flumes become inoperable. These emergency bypass systems are designated "Pre-dewatering Screen Emergency Fish Bypass System" and "Post-dewatering Screen Fish Bypass System".

The pre-dewatering system bypasses fish from just upstream of the primary dewatering system by means of a 5.5 foot diameter pipe controlled by a slide gate. The 5.5 foot diameter pipe transitions to a 30 inch diameter pipe and is routed to the post-dewatering fish bypass chamber and to the holding facilities or the river. Stoplogs are installed between the slide gate and primary dewatering screens to allow complete unwatering of the primary dewatering system for maintenance.

The post-dewatering system bypasses fish from just downstream of the secondary dewatering

system by means of a 3 foot by 4 foot vertical chamber, to a 30 inch diameter pipe and is routed to either the holding facilities or the river.

Fish Transportation System

Fish and transportation water leaving the primary and secondary dewatering systems are transported to either the holding facilities or the river by a 3 foot wide by 4 foot high U-shaped, shaded, galvanized, painted corrugated flume. This flume system design incorporates a 360 degree full circle loop that has a 30 foot centerline radius. The loop section is required to maintain similar channel slopes as a previously tested flume design.

<u>Site Visit Observations and Findings</u>

The following site visit observations and findings are based on SWEC's observations while visiting the site and interviews with project personnel. The magnitude of concern made in the following comments are subjective and are provided to give additional insight into system design and operation.

Off-Line Findings, Problems and Concerns with Current Systems

- Dewatering trapezoidal section has no brush/cleaning mechanism, it must be cleaned manually.

- Truck loading facilities - dewatering system drains too fast.

- Delay in fish passage is a problem in both the collection channel and the dewaterer. A way of moving fish downstream during normal operation and when dewatering. A "sonic device" may be appropriate. A floating sonic device could be placed in the upstream end of the collection channel and then retrieved downstream at the primary dewaterer. However, such a device might move too fast. Another option would be to wire the full length of the collection channel and primary dewaterer and have sonic devices activate in series. One drawback might be that a large amount of fish would end up entering the separator in a short period of time.

- Debris can overwhelm the primary dewaterer's screen cleaning system. An air-burst system in combination with a brush sweep would be ideal.

- Completely dewatering the collection channel and primary dewaterer requires hand removal of fish. The fish are scared by dewatering, netting, bucketing and people splashing around. It would probably be better to scare the fish out of the system with a sonic device prior to dewatering.

- Electrical systems should be backed up by air pressure systems to the extent possible and vice versa.

- A power outage at the primary dewaterer could cause problems, especially if prolonged. The motors for the cleaning brushes would not work. This is where an air burst system would be ideal. Flow control weirs would also be inoperable, but the can be moved with an air wrench.

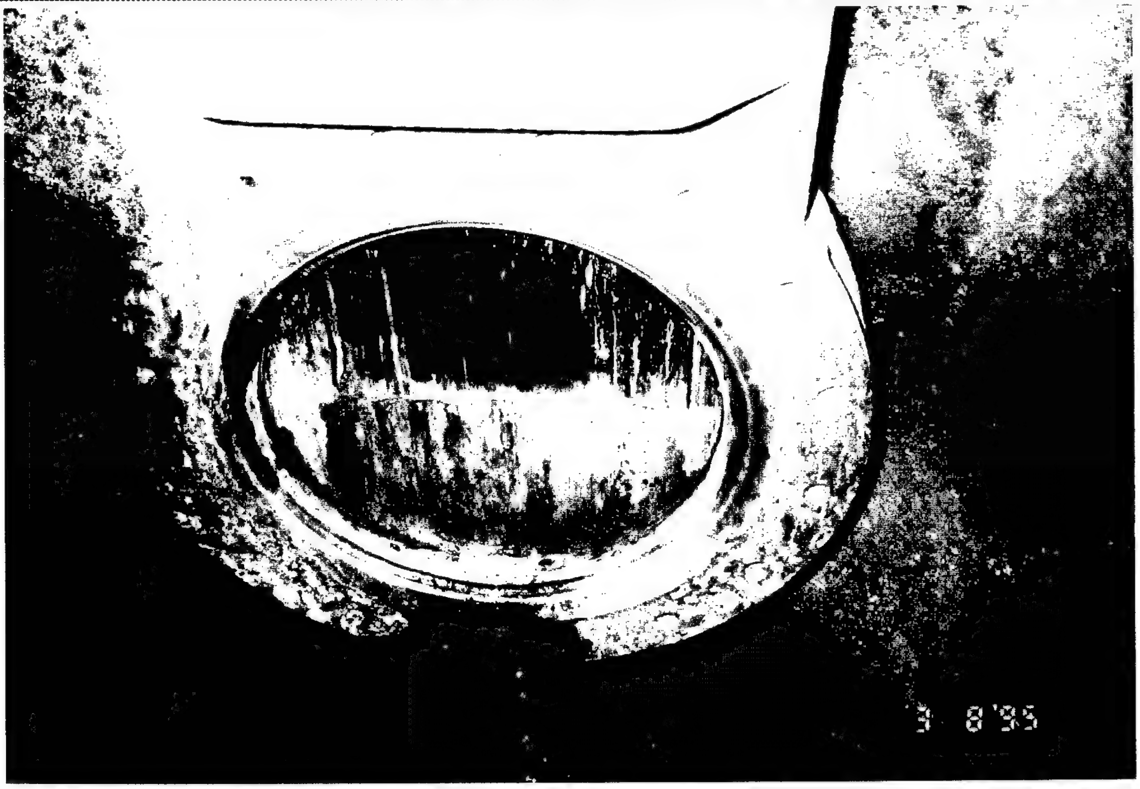
Attributes and General Comments with the Current Systems

- Overall system works well, maintenance items are labor intensive.

- Dewatering system is generally self cleaning with few trash problems. It has been shut down once due to leaves clogging the screens.

- The weirs and Milltronics equipment have been very reliable.

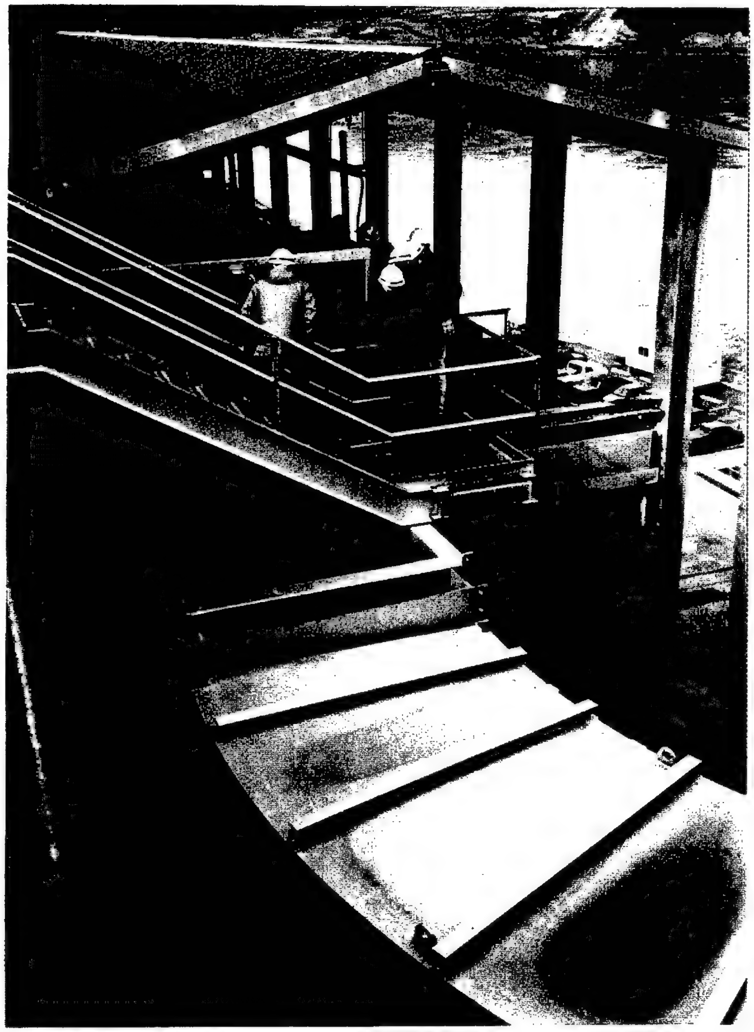
LITTLE GOOSE LOCK AND DAM
Lower Snake River - Washington



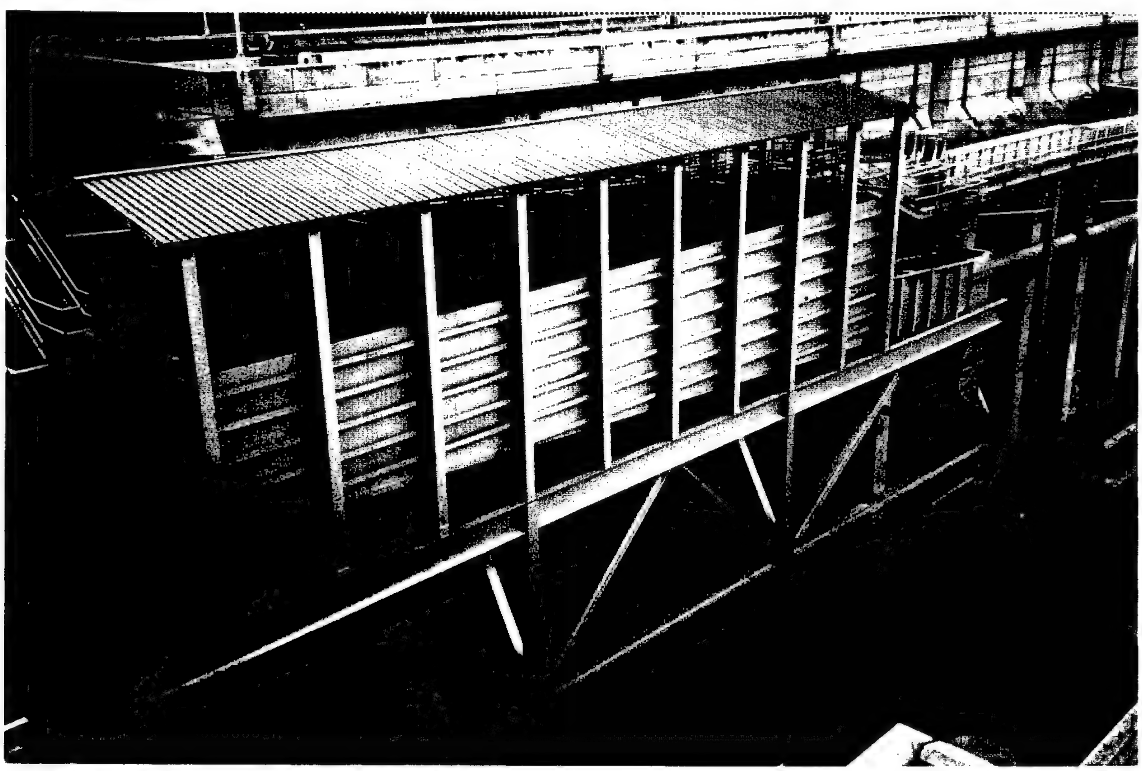
Close-up view of typical knife gate used to control gatewell orifice either open or closed. (Similar at all projects visited.)

Fish collection flume exiting dam extending to dewatering facilities.

LITTLE GOOSE LOCK AND DAM
Lower Snake River - Washington



Fish collection flume connection to dewatering facility.



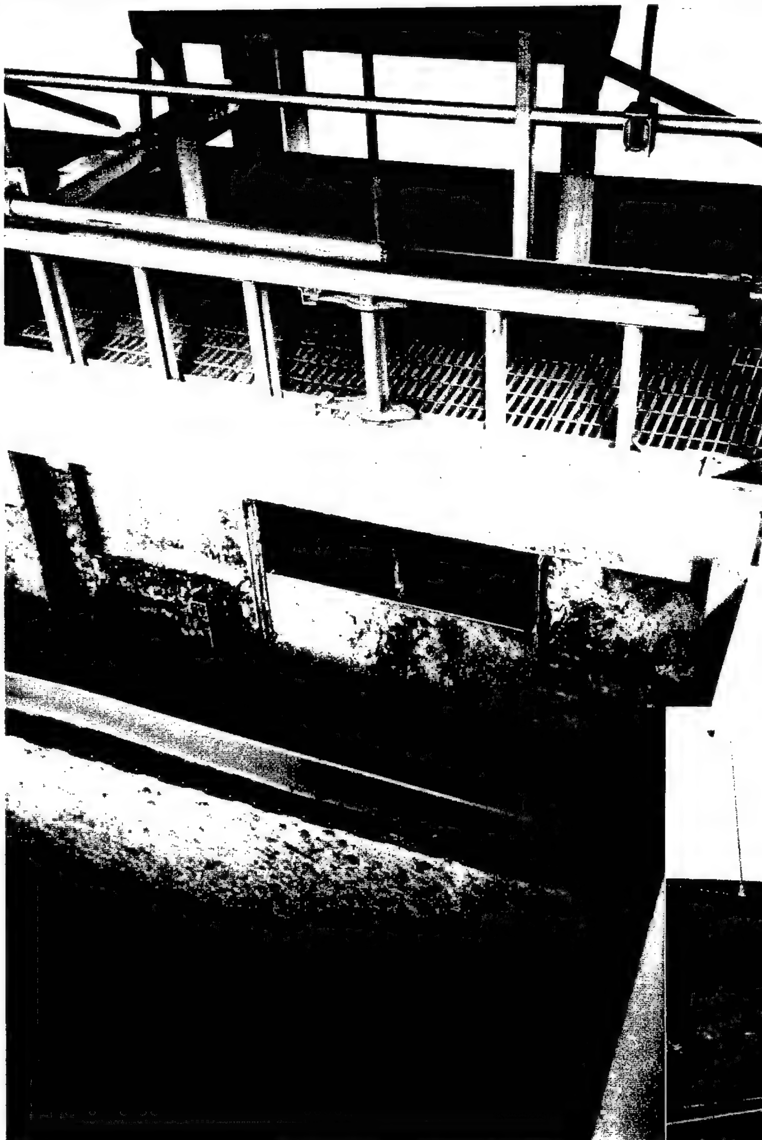
Dewatering facility (flow from left to right) discharging into corrugated metal flume (CMF) with shade cover.

LITTLE GOOSE LOCK AND DAM
Lower Snake River - Washington

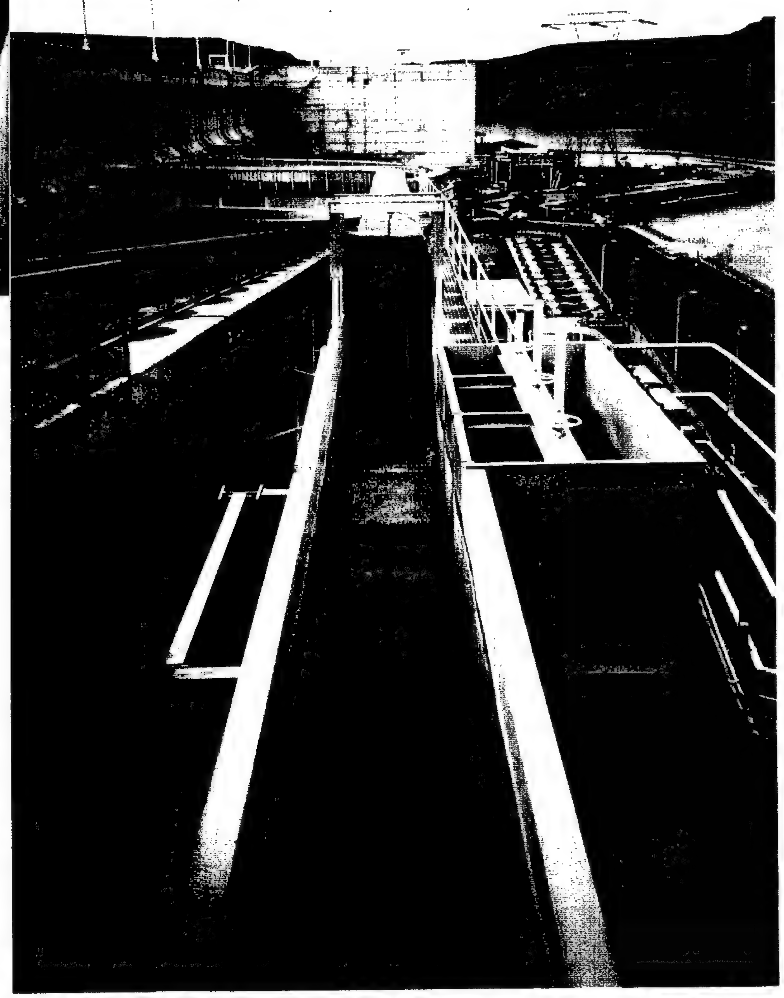
Fish transportation flume with loop to reduce effective slope extending from dewatering facility to fish handling facility.

Floor dewatering screens with converging section at downstream end. Right wall lower than left for emergency bypass. Brush cleaning system with chains mounted on sidewalls.

LITTLE GOOSE LOCK AND DAM
Lower Snake River - Washington



One of six weir gates to control floor dewatering discharge.



Fish transportation flume with secondary sidewall dewatering system (three weir gates behind perforated plates) immediately downstream of floor screen dewatering.

2.3 Lower Monumental Lock and Dam

General Project Description

Lower Monumental Lock and Dam is located 32 river miles upstream of Ice Harbor Lock and Dam at Snake River mile 42 near Kahlotus, Washington. The dam crest is approximately 3,800 feet long consisting of an embankment section extending from the left abutment to an 86-foot wide navigation lock, a south fish ladder, a 335-foot long gated spillway, a 656-foot long powerhouse, and a north fish ladder on the right abutment. The powerhouse contains six generators with total rated generating capacity of 810 megawatts (MW).

Lake Herbert G. West is impounded by the dam extending 28 miles upstream with a surface area of 6,590 acres. The normal operating headwater pool varies between elevation 537 feet (minimum) and elevation 540 feet (maximum). The normal operating tailwater pool varies between elevation 437 feet (minimum) and elevation 445 feet (maximum). Average Snake River flow at Lower Monumental Lock and Dam is about 50,000 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Juvenile fish approach the dam at various depths in the forebay, they follow the flow down into the turbine intakes and are diverted up into the gatewells by submerged screens. Juvenile fish entering the gatewell are discharged to the collection channel through tube-type orifices.

The collection channel runs the full length of the powerhouse from South to North. The collection channel transitions into a flume that routes the fish and water out the north end of the powerhouse and is carried on towers to the primary dewatering facilities. The primary dewatering system reduces the flow from 200 cfs - 300 cfs to 28 cfs - 43 cfs. The reduced flow enters a transportation flume which is carried on grade to the holding facilities or the river.

No mortality or descaling problems have been attributed directly to the collection/dewatering facilities.

Dewatering Systems

Primary dewatering is through the floor dewatering screen. The floor screen is divided into 9 sections; 8 rectangular sections each 10 feet long by 7 feet wide, the last (downstream) section is a trapezoidal section 10 feet long transitioning from 7 feet wide to 3 feet wide. Design flows through the dewatering screens range up to 257 cfs.

The amount of water discharging through the primary dewatering screen and the water level in the main channel are regulated by a control weir system. The control weir section consists of: a baffle arrangement to provide uniform flow through the screen; 2 - two foot high by nine foot long and 7 - two foot high by eight foot long discharge orifices that route flows into a 4 foot wide by 90 foot long vertical chamber and 9 - four foot long by 4.5 foot tall automatic weirs

that direct flow into a 90 foot long by 6 foot wide side chamber. The side chamber floor slopes to a downwell 21 feet long by 6 feet wide. A 66 inch diameter drain pipe located at the invert of the downwell routes excess water to the fish ladder. A 90 foot long overflow weir located adjacent to the dewatering screen is set 4.6 feet below the top of the outside walls and prevents the flows from overtopping the structure.

Secondary dewatering occurs in the 3 foot wide flume section immediately downstream of the primary dewatering system. Secondary dewatering uses perforated plates on the side walls. Weirs directly behind the plates control and regulate the flow entering the corrugated flume. Excess water taken off at the secondary dewatering is piped directly to the side chamber.

Trash is a concern at the project since it clogs orifices and dewatering screens. Debris commonly consists of sticks, algae, leaves and wheat chaff. Dewatering screens which typically use wedge-wire with 1.75mm bars spaced 2mm apart and are highly susceptible to clogging by leaves and wheat chaff. Debris is removed by brushes which travel the screen length from upstream to downstream. Debris usually ends up in the raceways and must be removed and disposed of manually.

Screen cleaning is by a overhead mounted trolley with an arm to which the brushes are attached. The brush assembly is lowered into the flow path until the brushes make contact with the screen. The trolley moves the brushes downstream to remove debris. An air bubbler is being installed for the '95 season to remove debris from the trapezoidal section. Prior to the air bubbler installation debris was removed by hand.

Emergency Fish Bypass System

Two emergency fish bypass systems are incorporated to route juvenile fish directly into the river in the event that either the primary dewatering screens, transportation flume or handling facilities become inoperable. These emergency bypass systems are designated "Primary Dewatering Structure Bypass" and "Corrugated Metal Flume Bypass".

The primary dewatering structure bypass routes fish from immediately upstream of the primary dewatering system by means of a bypass chamber (downwell) in the flume floor. Orifice flows are shut down for installation of stoplogs, removal of the perforated floor screen covering the bypass chamber and opening the bypass line knife gate valve. The bypass chamber consists of a 7 foot square opening transitioning to a 3 foot diameter pipe. The 3 foot diameter pipe transitions to a 2.5 foot diameter pipe then to a 2 foot diameter pipe and is routed to the river.

The corrugated metal flume bypass routes fish from just downstream of the secondary dewatering system by means of a 2 foot diameter pipe controlled by a knife gate valve. The valve position is fully opened during bypass operation. Orifice flows are reduced to allow for installation of stoplogs immediately upstream of the corrugated metal flume, removal of perforated plate covering the bypass pipe and opening the knife gate valve. This bypass system uses three pipes (1.5 feet, 1.67 feet and 2 feet in diameter) which take water from the floor of

the primary dewatering structure to provide makeup water for fish discharged to the river.

Fish Transportation System

Fish and transportation water leaving the primary and secondary dewatering systems are transported to the holding facilities by a 3 foot wide by 4 foot high U-shaped, shaded, corrugated flume. A switch gate upstream of the holding facilities routes fish to the river through a 2.5 foot diameter HDPE pipe or to the holding facilities.

<u>Site Visit Observations and Findings</u>

The following site visit observations and findings are based on SWEC's observations while visiting the site and interviews with project personnel. The magnitude of concern made in the following comments are subjective and are provided to give additional insight into system design and operation.

Off-Line Findings, Problems and Concerns with Current Systems

- Primary dewatering trash sweep is cable driven. The cable requires replacement approximately 3 times throughout the year. High maintenance item.
- One occurrence (1993) of completely plugging the dewatering screen with wheat chaff. The entire dewatering facility overflowed. Attributed to run-off from tributary (Palouse River).
- Fish hold in the dewatering structure and collection channel, doesn't seem to be much of a problem.
- Dewatering the primary dewaterer requires netting adult and juvenile fish and carrying them out in a can.
- Electric valve operator indicators frequently malfunction.
- Dewatering facility electrical supply has a high exposure to failure and should be provided with redundancy or back-up.
- Features that would cause a cascade effect if they failed are: Facility electrical supply, Orifice air supply, Facility air supply and Raw water supply.
- Pneumatic orifice slide gates stick, more air pressure may be required.
- Electric butterfly valves stick, probable cause maybe infrequent use.

On-Line Findings, Problems and Concerns with Current Systems

- The drive mechanism for the brush trolley appears to be the "weak-link" in the operation of the cleaning system. The drive rope is wrapped around a friction sheave which causes the rope to drag against itself, resulting in fraying of the rope and reduced rope life. At the time of inspection the wire rope appeared to be near failure.

- The primary dewatering system worked smoothly with no reported maintenance problems.

- Dewatering control structure - Control valve number 8 has no valve position indicator. Can cause total dewatering of system if adjusted and left unattended. This control valve has an indicator for the valve fully open or fully closed, which is how the valve was designed to be operated. Staff should be instructed on the hydraulics of this system and how it was designed to be operated.

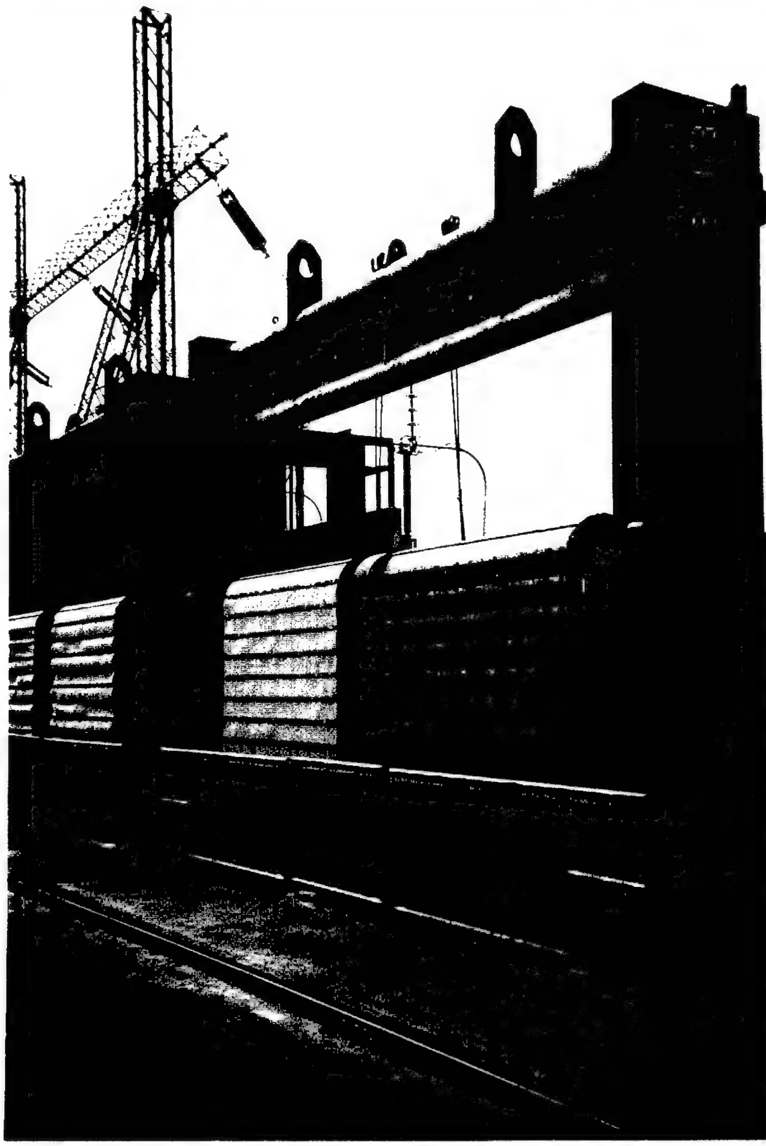
- The final dewatering section, just upstream of the separator, is wedge wire (Johnson) screen. The rate of dewatering appeared to be too rapid, and in some areas the screen would draw air. It was related that in the past there have been attempts to "tune-out" this problem, but these attempts resulted in moving the problem to another location on the screen. Other sites (Lower Granite and McNary) use perforated plate rather than wedge-wire screen and do not appear to have an air entrainment problem.

Attributes and General Comments with the Current Systems

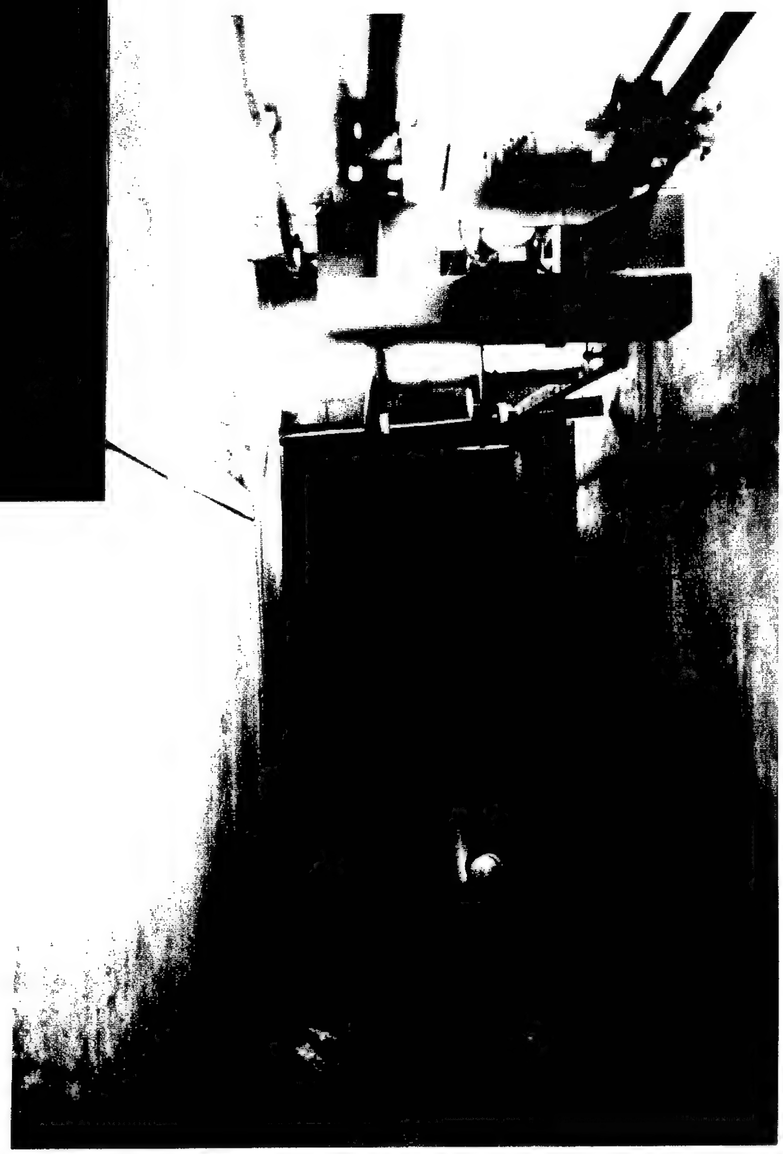
- Currently installing bubbler system under dewatering screen for the '95 season.

- Overall system works well, most problems are maintenance items.

LOWER MONUMENTAL LOCK AND DAM
Lower Snake River - Washington



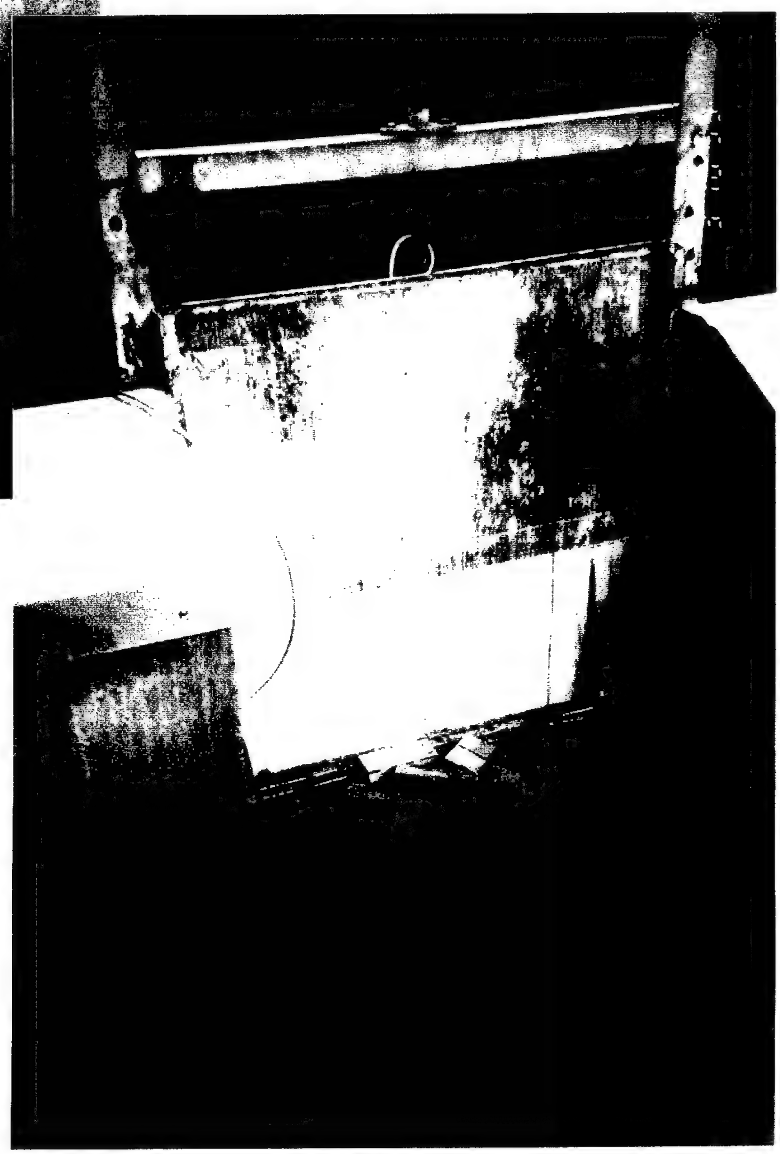
Typical 20-foot high submerged traveling screens (STS) with plastic mesh raised to operating deck level for inspection and maintenance. (Similar at all projects visited.)



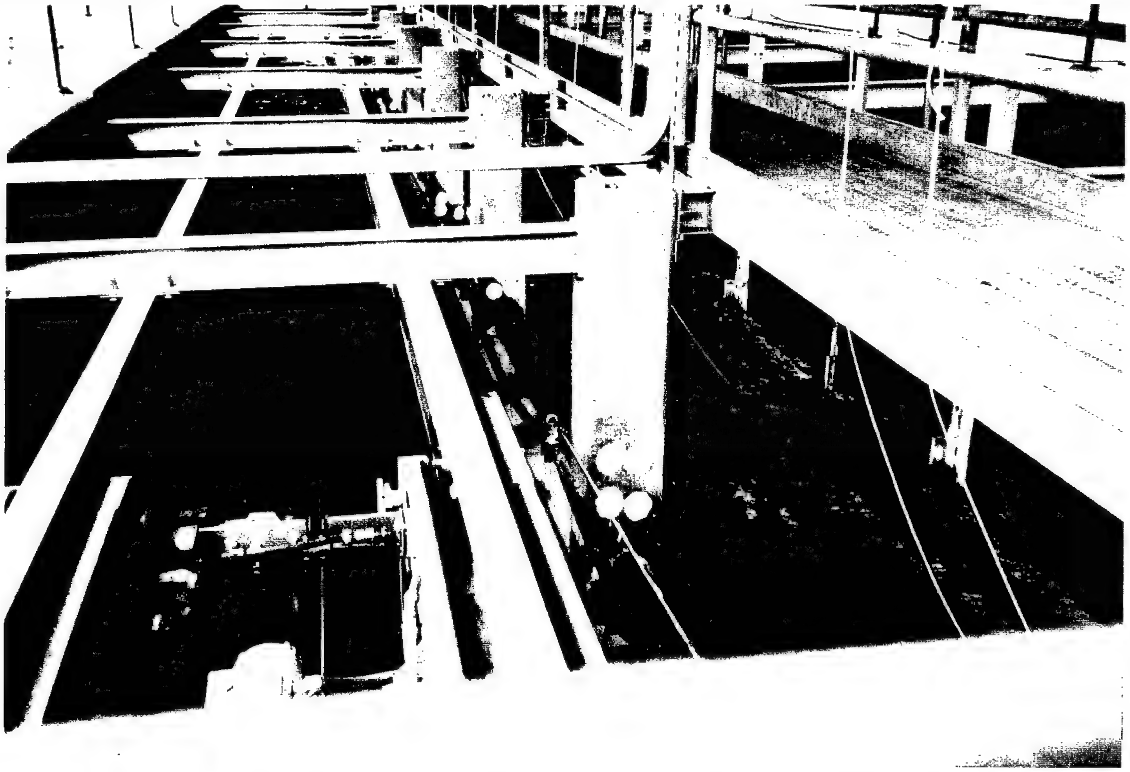
Fish transportation flume (looking upstream) discharge end into dewatering facility. Floor screens covered with plywood during maintenance work.

LOWER MONUMENTAL LOCK AND DAM
Lower Snake River - Washington

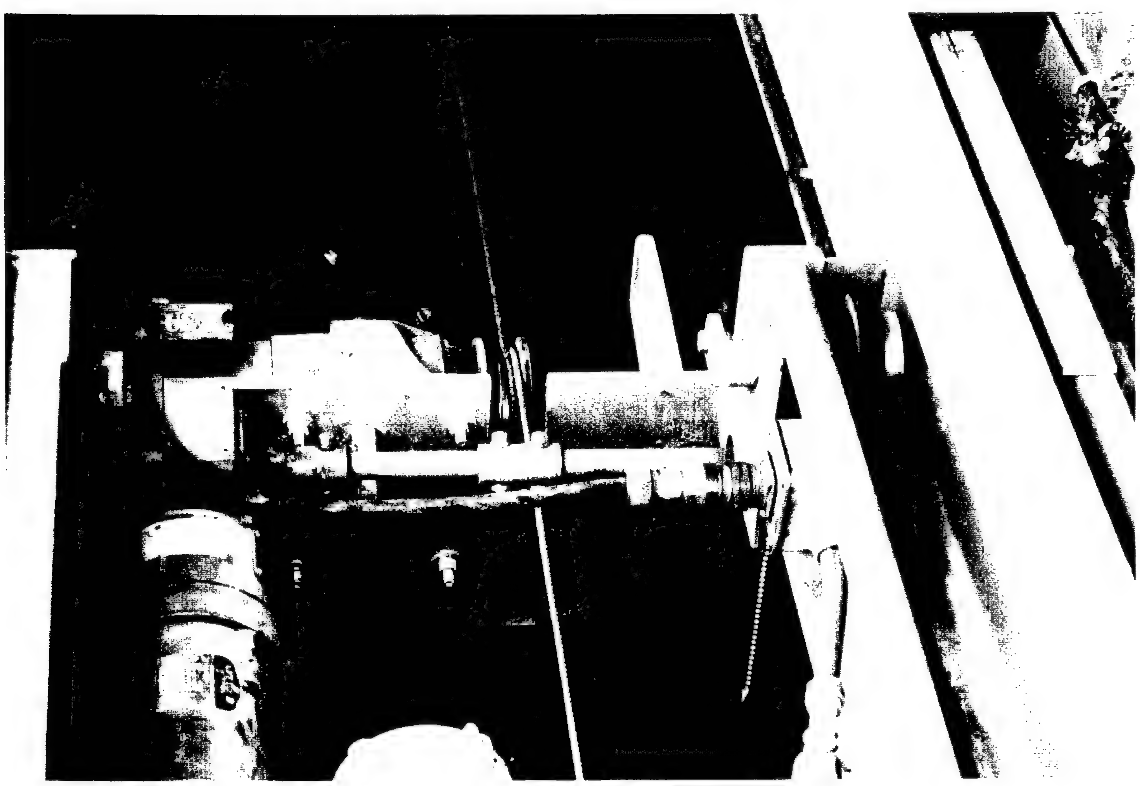
Dewatering facility with emergency overflow weirs along right wall. Floor screens covered with plywood during maintenance work.



One of several side channel weir gates to control water level in dewatering channel.

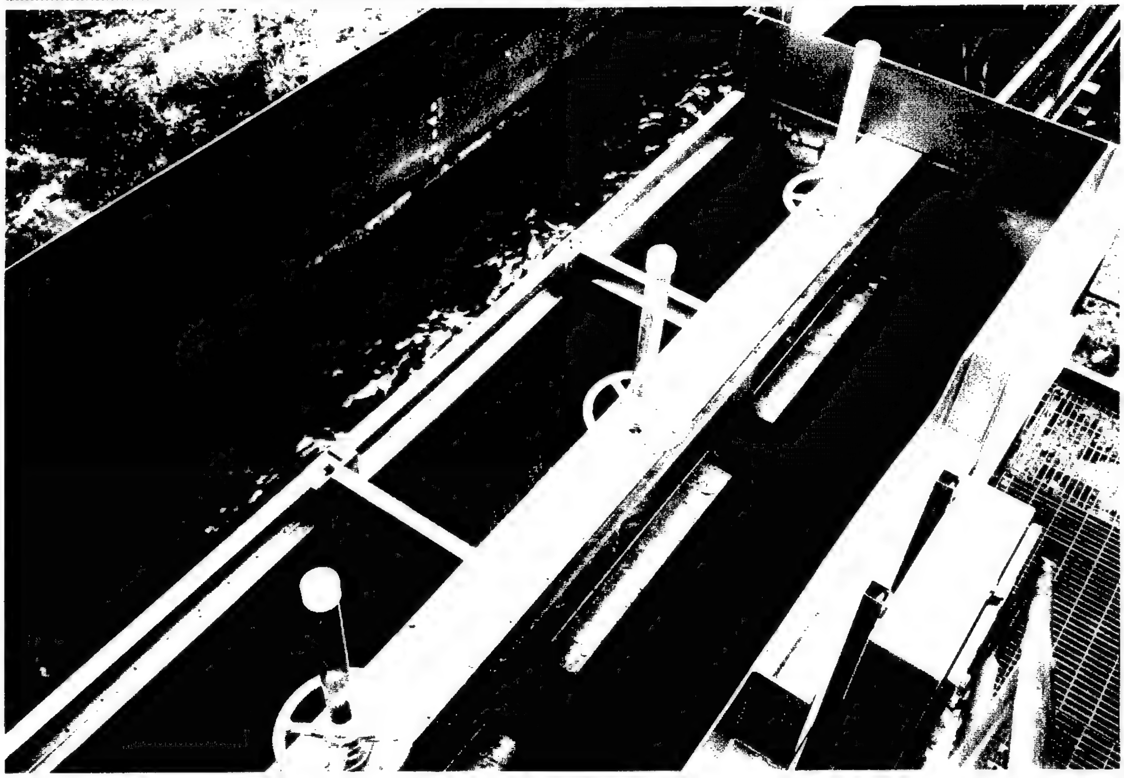


Downstream view of dewatering facility. Brush system for screen cleaning in lower left. Brown overflow weirs in center of photo for emergency discharges. Discharge in lower right of photo passing over weir gates into pipe that returns to river.

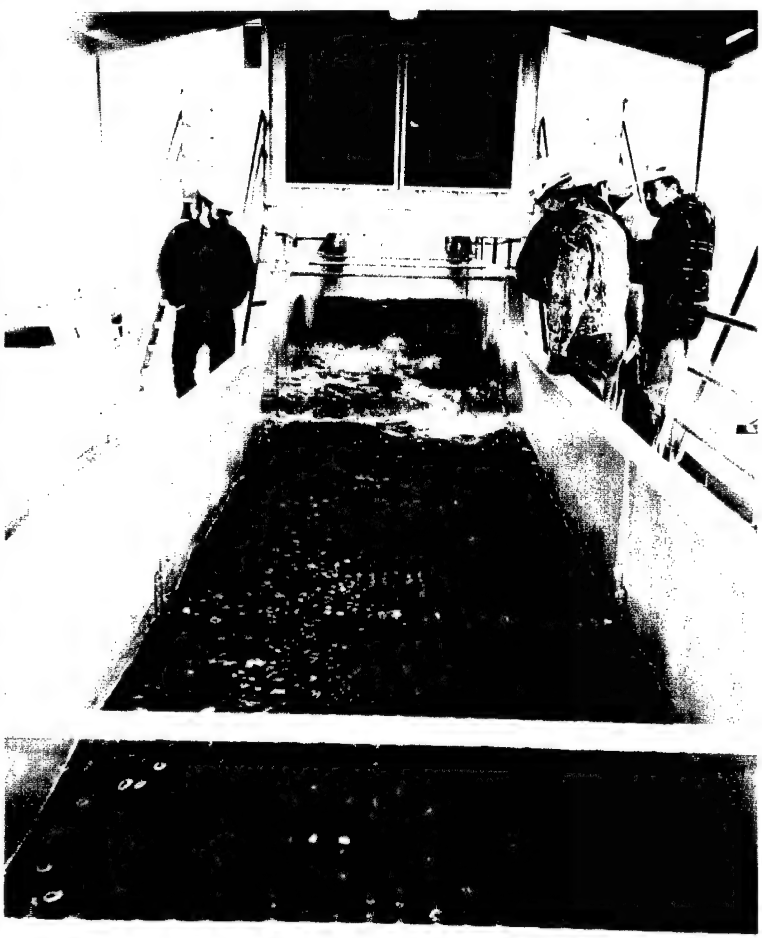


Closeup view of floor screen brush system drive motor and wire rope. Note excessive wear on wire rope in top center of photo.

LOWER MONUMENTAL LOCK AND DAM
Lower Snake River - Washington



View of secondary dewatering side wall screens and weir gates <u>not</u> in operation in upstream reach of transportation flume.



Upstream view of discharge into fish separator. Note turbulence in upper center of photo where floor dewatering system is located. Right and left halves of dewatering system cannot be adjusted to perform similarly.

2.4 McNary Lock and Dam

General Project Description

McNary Lock and Dam is located 76 river miles upstream of John Day Dam at Columbia River mile 292 near Umatilla, Oregon. The dam crest is approximately 7,365 feet in length consisting of an embankment section that extends from the south abutment to a 1,422-foot long powerhouse, a south fish ladder contained in the south embankment section, a 1,310-foot long gated spillway, a north fish ladder, an 86-foot wide navigation lock, and a north embankment section that extends from the navigation lock to the right abutment. The powerhouse contains fourteen generators with a total rated generating capacity of 1,120 megawatts (MW).

Lake Wallula is impounded by the dam extending 62 miles upstream with a surface area of 38,800 acres. The normal operating headwater pool varies between elevation 335 feet (minimum) and elevation 340 feet (maximum). Normal operating tailwater pool varies between elevation 257 feet (minimum) and elevation 265 feet (maximum). Average Columbia River flow at McNary Lock and Dam is about 189,000 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Juvenile fish approach the dam at various depths in the forebay, they follow the flow down into the turbine intakes and are diverted up into the gatewells by submerged screens. Juvenile fish entering the gatewell are discharged to the collection channel through tube-type orifices.

The collection channel runs the full length of the powerhouse from North to South. Before exiting the powerhouse, primary dewatering screens reduce the flow from 400 - 690 cfs to 30 - 40 cfs. The reduced flow enters a transportation flume which is routed out the south end of the powerhouse and is carried on towers to the holding facilities or the river.

No mortality or descaling problems have been attributed directly to the collection/dewatering facilities. Fish may hold in eddies created in the transition area between the side and floor dewatering sections. This is generally thought unlikely to be a substantial problem in delaying passage or increasing stress but may be of concern to the fisheries agencies.

Dewatering Systems

McNary's primary dewatering system is unique since it handles a large flow and employs side dewatering along with floor dewatering.

Primary dewatering is through the floor dewatering screen. The floor screen is divided into three sections, a rectangular section 67.5 feet long x 13.5 feet wide, a trapezoidal section 24 feet long transitioning from 13.5 feet wide to 3.0 feet wide and a secondary dewatering section that is the last 10 feet of the trapezoidal section. Wedge-wire screens are used with bars oriented in-line and parallel to the flow. Design flows through the floor screens range up to 420 cfs.

Primary dewatering is also through the side dewatering wedge-wire screens. The side screen area is 70 feet long x 10 feet high and bar orientation is parallel to the flow. Design flows range from 0 to 280 cfs. For minimum collection channel flows of 406 cfs the side dewatering screen is not in operation.

Excess collection channel flows withdrawn from the north half of the side dewatering system (up to 140 cfs) discharges into the river through the ice/trash sluiceway north of the powerhouse. Excess collection channel flows withdrawn from the southern half of the side dewatering system (up to 140 cfs) is used as fish ladder attraction water. Excess flows withdrawn from the floor dewatering system are split with 75 cfs routed to the holding facilities and the remainder (up to 345 cfs) used as fish ladder attraction water.

Trash is a concern at the project since it clogs orifices and dewatering screens. Debris commonly consists of sticks, algae, leaves and wheat chaff. Dewatering screens consist of 1.75 mm bars spaced 2 mm apart and are highly susceptible to clogging by leaves and wheat chaff. Debris is removed by brushes which travel the screen length from upstream to downstream. Debris collects in the raceways and must be removed and disposed of manually.

The rectangular floor screens are cleaned by a ceiling mounted trolley with an articulated (scissor) arm to which the brushes are attached. One set of brushes are used to clean the rectangular screen section. The assembly is lowered into the flow path until the brushes contact the screen. The trolley moves the brushes downstream to remove debris.

The trapezoidal floor screens are cleaned by a ceiling mounted trolley, similar to the rectangular screen brush system, except the trolley pivots to allow paralleling the converging walls.

Side dewatering screens are cleaned by a wall mounted, automated traveling brush that moves from upstream to downstream.

Emergency Fish Bypass System

An emergency fish bypass system is incorporated to route juvenile fish directly into the river in the event that either the primary dewatering screens or the transportation flumes become inoperable.

If the emergency bypass system is used, several steps must be taken to make the system operable. First, the orifices must be closed to allow installation of bulkheads upstream of the primary dewatering system. The emergency bypass floor panels must be removed and the orifices re-opened. Once in the collection channel, the juvenile fish pass through the 8 x 8 foot square opening in the collection channel floor, and are transported through the ice/trash sluiceway that discharges to the river North of the powerhouse.

Fish Transportation System

Fish and transportation water leaving the collection channel dewatering system are transported to either the holding facilities or the river by a 3 foot wide by 4 foot high smooth flume, a 36 inch diameter smooth flume, a corrugated metal flume (CMF) and a 30 inch diameter smooth flume.

Site Visit Observations and Findings

The following site visit observations and findings are based on SWEC's observations while visiting the site and interviews with project personnel. The magnitude of concern made in the following comments are subjective and are provided to give additional insight into system design and operation.

Off-Line Findings, Problems and Concerns with Current Systems

- Currently trash/debris removal from the raceways is a large effort.
- Dewatering bar screen spacing is smaller than the submerged bar screen in gatewell due to different spacing criteria with higher concentrations of fish.
- The transition (expansion from 9 feet to 13.5 feet wide) between side dewatering and floor dewatering creates a fish holding spot (eddy).
- There is no auxiliary water supply system redundancy for the handling facilities if the dewatering system becomes inoperable.
- Personnel does not like centralized dewatering at this facility. The old system had screens spaced along the full collection channel length. Excess water entering the collection channel from the orifices was removed throughout the entire collection channel. This system was more forgiving if a screen became plugged. With centralized dewatering a failure in the screens results in complete system shutdown.
- Some of the dewatering control gates are not rising stem type. This style gate has caused excessive maintenance of the leaf drive nut due to the difficulty of lubricating the unaccessible drive nut.
- Dewatering screens cleaning systems (rectangular to trapezoidal) can overlap. There is an interlock to prevent simultaneous operation of the cleaning systems, however if the interlock fails there are no alarms installed to detect if the brushes overlap and lock up.
- System water level alarms are not redundant.
- Unseating type gates have caused binding problems in the past.

- No flow measurement devices are currently used in the system.

- Screen plugging seems to be the worst problem. A water backflush for cleaning the dewatering screens maybe appropriate.

- A reinforced perforated plate primary dewatering system may be easier to keep clean.

- Implementation of an air-burst screen cleaning system would complement the existing brush system.

- Biggest problem is temperature shock of fish from encountering thermal gradients in the reservoir and while passing through the system. These shocked, incapacitated fish are unable to swim effectively and become impinged on the dewatering screens.

- The dewatering sluice gates have not handled the level of vibrations and flow energy that they are supposed to and have been very difficult to operate due to alignments shifts and gearbox failure.

On-Line Findings, Problems and Concerns with Current Systems

- The excess water discharge to the down well produces a continuous fine mist in collection channel dewatering screen area. This may present an adverse effect on electric/controls equipment.

- Juvenile fish hold-up in the transition section from the side dewatering to the floor dewatering and in areas on the floor dewatering screen where there is a break in the flow path.

- The floor dewatering screen debris removal brushes worked smoothly and appeared to be effective. The sidewall dewatering system was off-line at the time of the inspection. The primary driver gear box had failed.

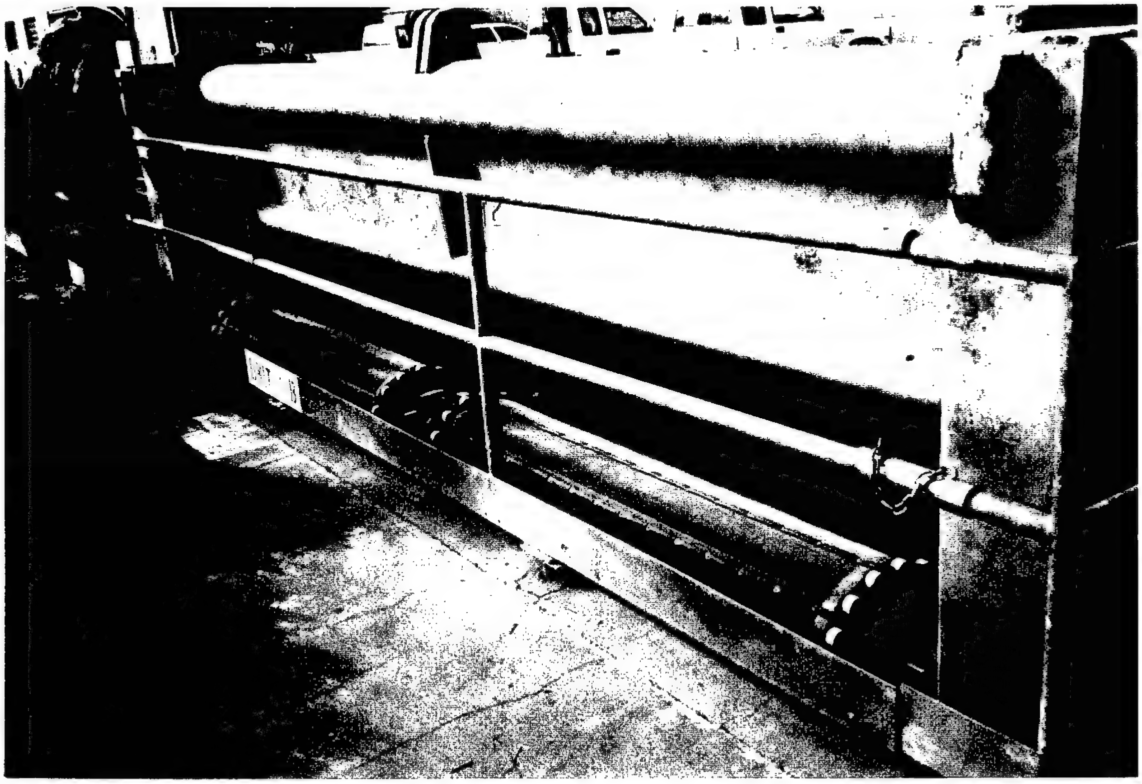
Attributes and General Comments with the Current Systems

- The majority of the system is fish friendly, overall the system performs as designed.

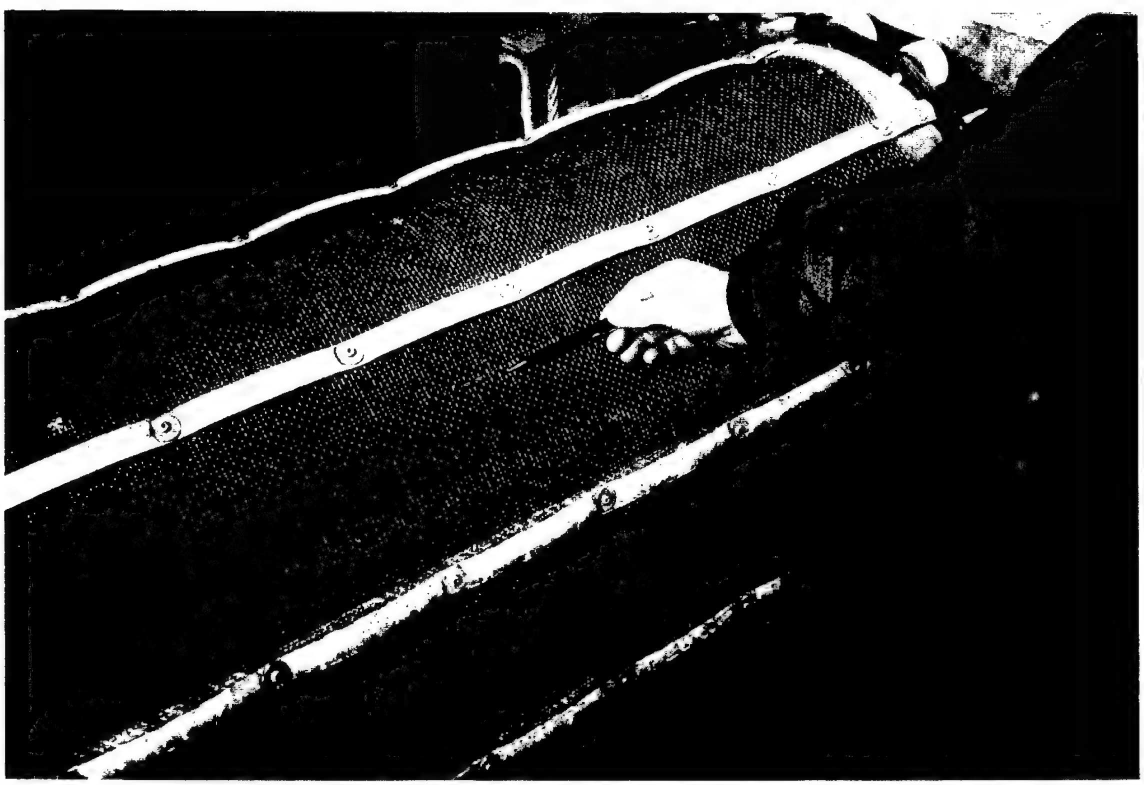
- In the Spring typical debris includes tumbleweeds and dead leaves and grasses while the late summer/fall produces more aquatic plant material. Woody material is usually more prevalent early in the season and is highly variable in quantity from year to year.

- Fairly good system control is maintained with ability to work with deadband and sensitivity adjustments as long as both dewatering valves are working and rapid changes do not occur in generator loads affecting the orifice discharges.

McNARY LOCK AND DAM
Columbia River - Washington/Oregon

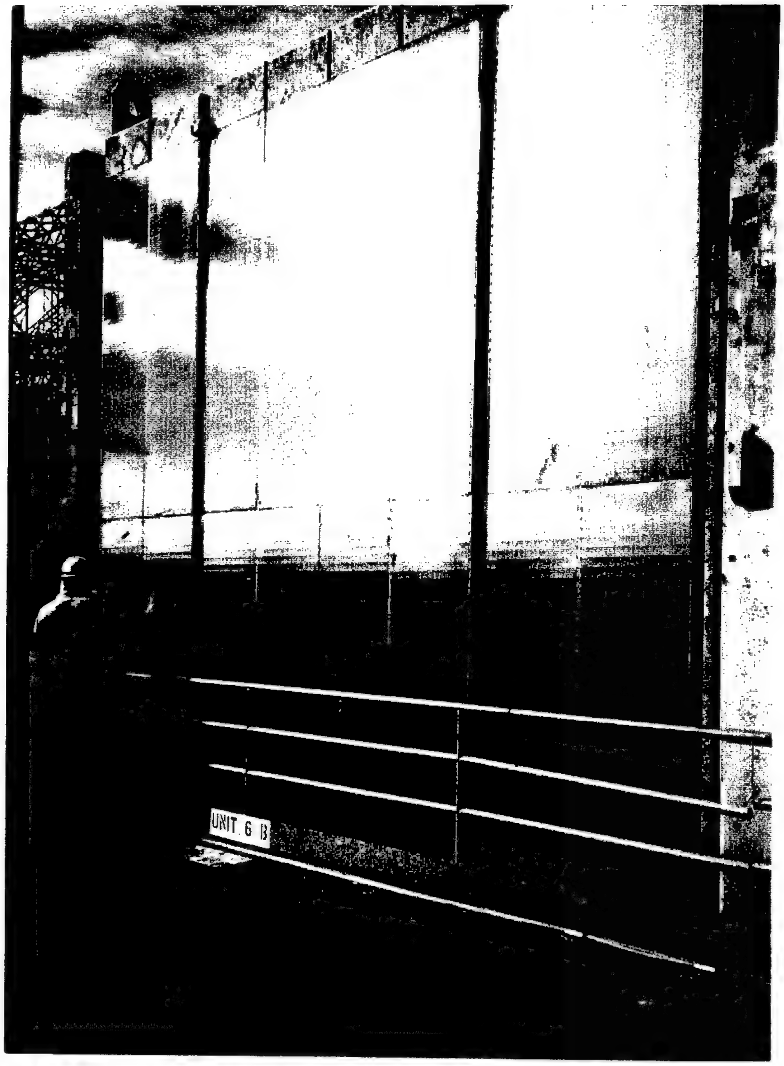


Typical 20-foot high submerged traveling screens (STS) raised to operating deck level. (Similar at all projects visited.)

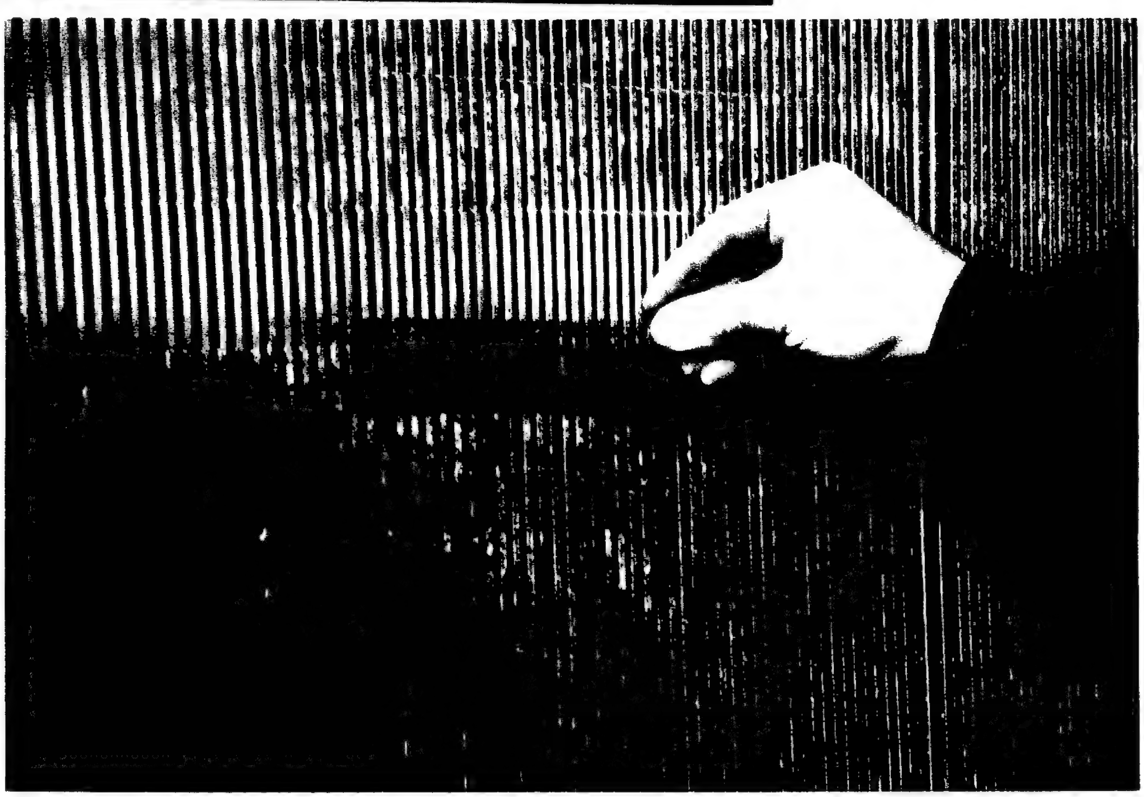


Close-up view of plastic mesh screen used in STS's. (Similar at all projects visited.)

McNARY LOCK AND DAM
Columbia River - Washington/Oregon



Extended submerged bar screen (ESBS) raised to operating deck level to be installed for testing during 1995 operations.

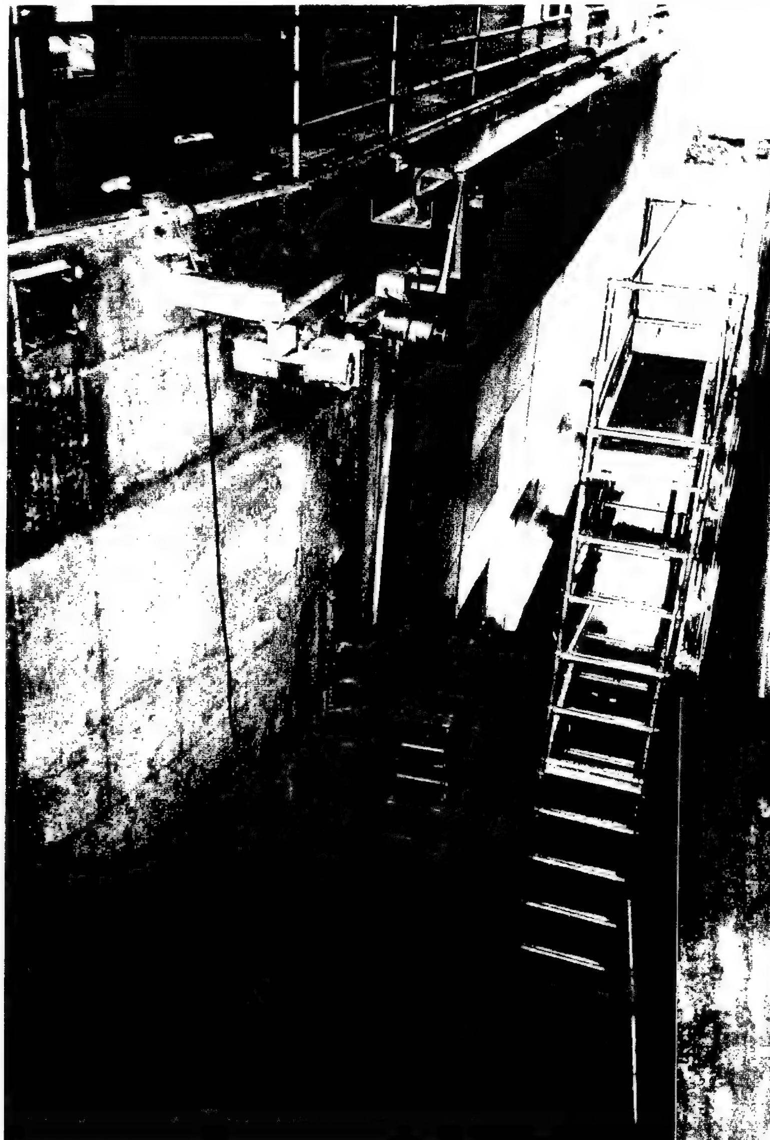


Close-up view of 1.75 mm bar with 2.0 mm clear space bar screen used on submerged bar screens for testing.

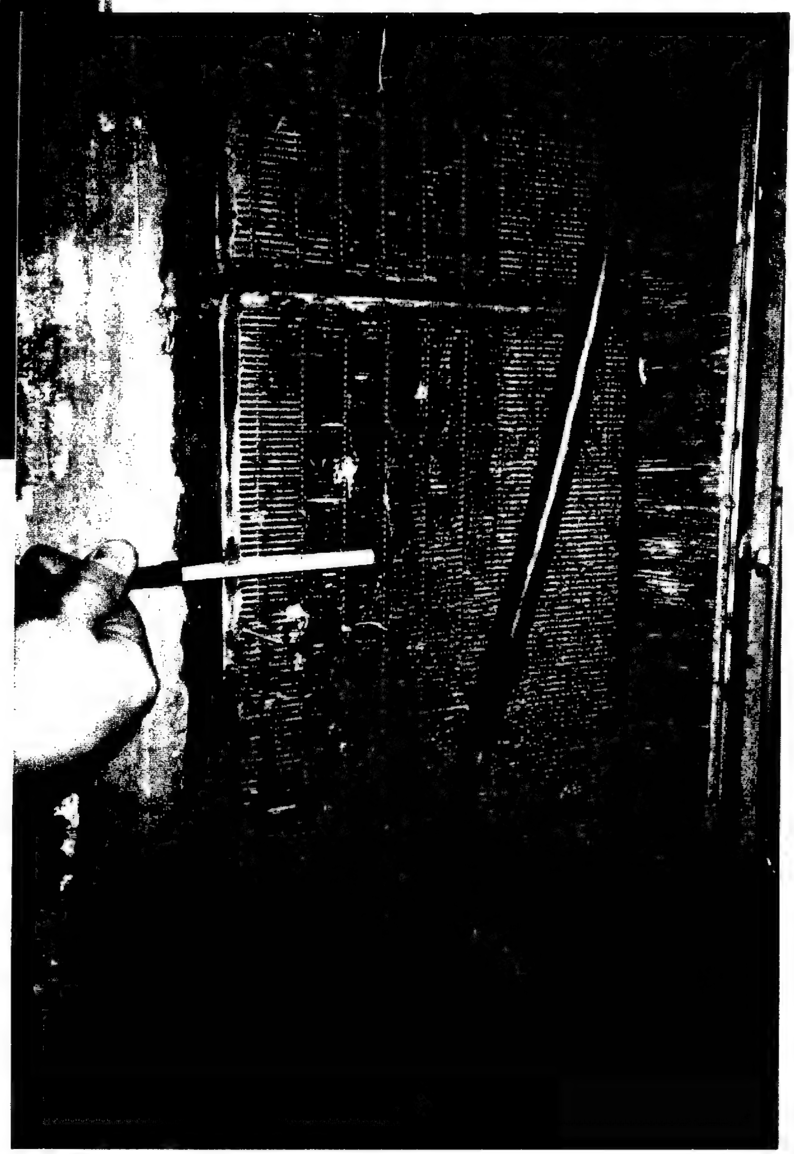
McNARY LOCK AND DAM
Columbia River - Washington/Oregon

Ice/trash sluiceway weir gate between piers. Ice/trash sluiceway with collection channel in left of photo. Note the floating debris.

Ice/trash sluiceway converted to juvenile fish collection channel looking upstream. Knife gate operators for gatewell orifices above grating along left wall.



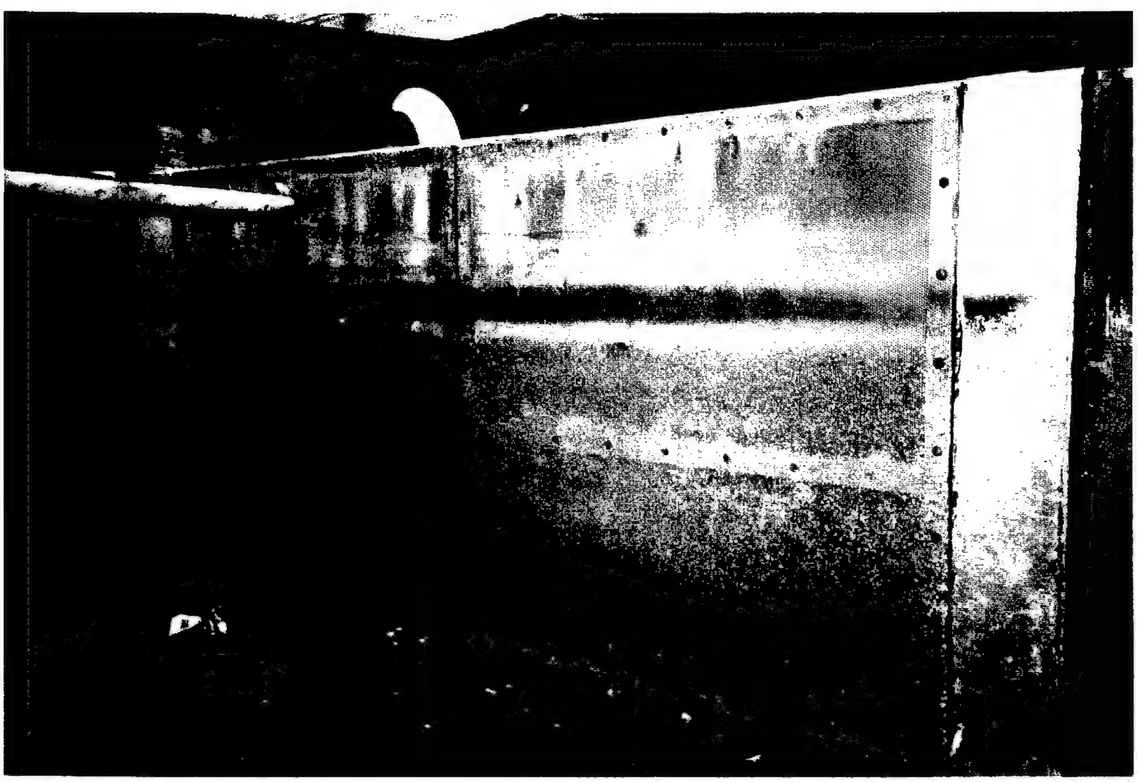
Side channel dewatering screens with automatic brush cleaning system (looking upstream).



Close-up view of submerged bar screen for side channel dewatering with horizontal bars.

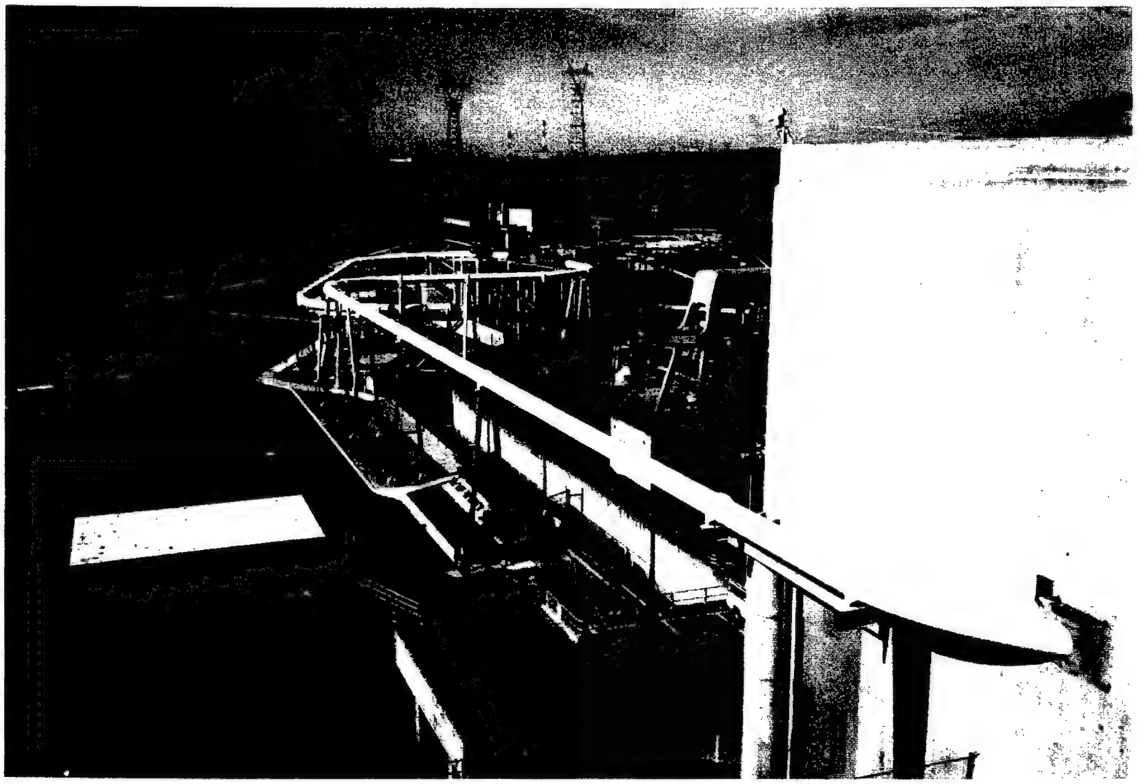
McNARY LOCK AND DAM
Columbia River - Washington/Oregon

Floor dewatering system with bar screens looking downstream with converging walls and inclined floor screens. Beams mounted above support brush cleaning systems in converging section.

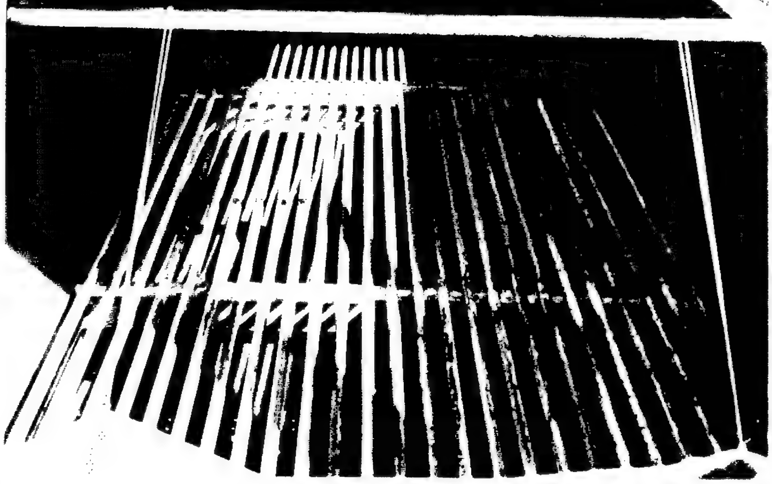


Side channel dewatering screens with weir gates behind immediately upstream of fish transportation flume.

McNARY LOCK AND DAM
Columbia River - Washington/Oregon

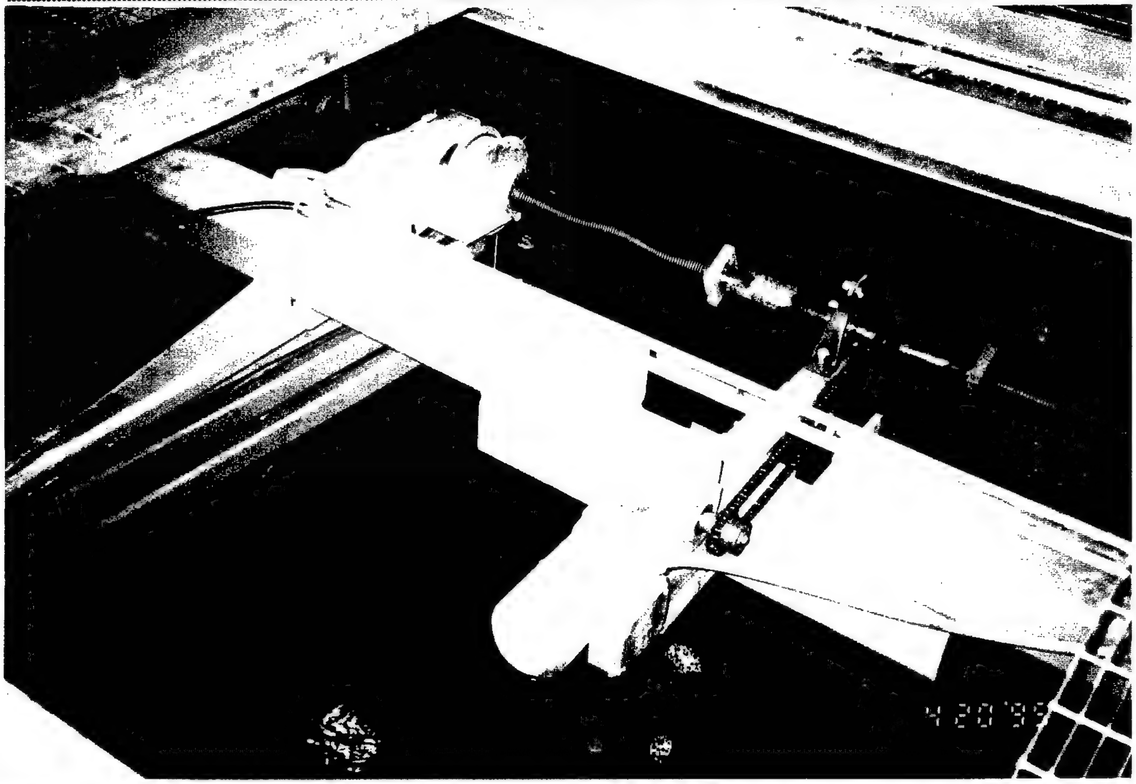


Steel fish transportation flume from collection channel to fish handling facility.

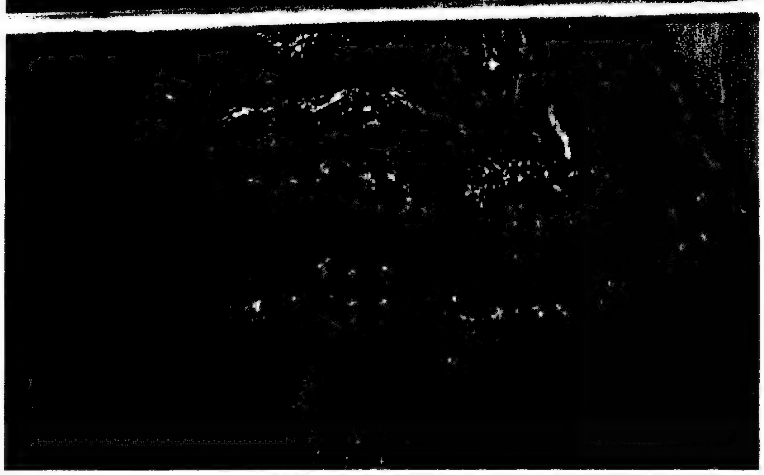


Fish sorting facility looking upstream toward outfall of fish transportation flume. (Sorting facilities similar at all projects visited.)

McNARY LOCK AND DAM
Columbia River - Washington/Oregon



Drive mechanism to raise and lower the brush to clean the inclined rectangular floor screens.



Upstream view of fish separator flowing about 30 to 40 cfs. No signs of juvenile fish passing through the system at this project on this date.

2.5 The Dalles Lock and Dam / Northern Wasco County P.U.D.

General Project Description

The Dalles Lock and Dam is located 192 river miles upstream of the mouth of the Columbia River near The Dalles, Oregon. Lake Celilo is impounded by the dam extending 24 miles upstream ending at the John Day Lock and Dam. The dam consists of a south abutment, south fish ladder, powerhouse, non-overflow section, spillway, north fish ladder, fish passage facilities, non-overflow section, navigation lock and north abutment. The powerhouse contains 22 generators with a total rated generating capacity of 1,807 megawatts (MW).

The north fish ladder attraction water flow channel between the navigation lock and the spillway was recently retrofit by Northern Wasco County P.U.D. to include a 5 MW turbine generator unit for using the fish ladder attraction flow to generate power. The new hydroelectric facility passes the existing fish ladder attraction water supply through a dewatering section, penstock and a separate powerhouse.

Description of Existing Juvenile Fish Facilities

The Dalles / Wasco juvenile fish passage facilities are unique in that a public utility added a juvenile bypass on the existing fish ladder auxiliary attraction water supply. The utility, Northern Wasco County PUD, installed a 5 MW turbine generator unit at the fish ladder to use the 800 cfs attraction flow for power generation. The attraction flow is controlled by the turbine generator unit which discharges into the tailrace.

Fish entering the turbine intake are guided through the intake channel to the dewatering system. The dewatering system consists of a bank of fixed, vertical, stainless steel, wedge-wire screens converging to the intakes side wall. The flow routed to the fish bypass is approximately 10 cfs, which downwells into a transportation pipe and is routed back to the river downstream of the right bank fishway. The bypass flow can be routed through collection facilities, immediately upstream of the transportation pipe, for fish sampling and testing.

Dewatering Systems

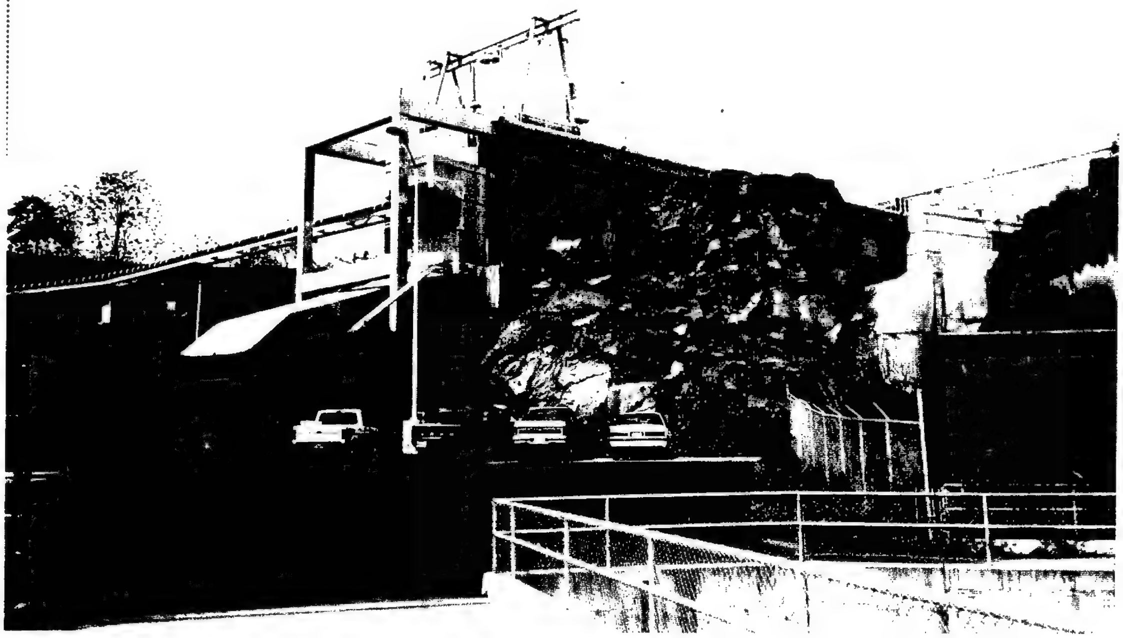
The dewatering system design is a single converging channel. The fixed vertical wedge-wire screens converged to a channel side wall on the downstream end. The screen material is stainless steel wedge-wire. The majority of the dewatering occurs at the downstream end of the channel. Flow distribution through the screens is controlled by spaced aluminum stoplogs supported by nuts on threaded rod. The porosity is changed by lifting a stoplog section onto the deck and turning the nuts to reduce or enlarge the space between the stoplogs. This type of system is difficult and time consuming to hydraulically tune since spacing adjustment is limited. Several "hot-spots" were noted during the inspection. One cause of the increase flow through the screen in certain areas (hot-spots) may be caused by the penstock intake which is located at the downstream end of the dewatering screens. The penstock intake has a large continuous

vortex which does not appear to have any adverse effects on unit operation since there were no reported problems such as air entrainment or penstock surging.

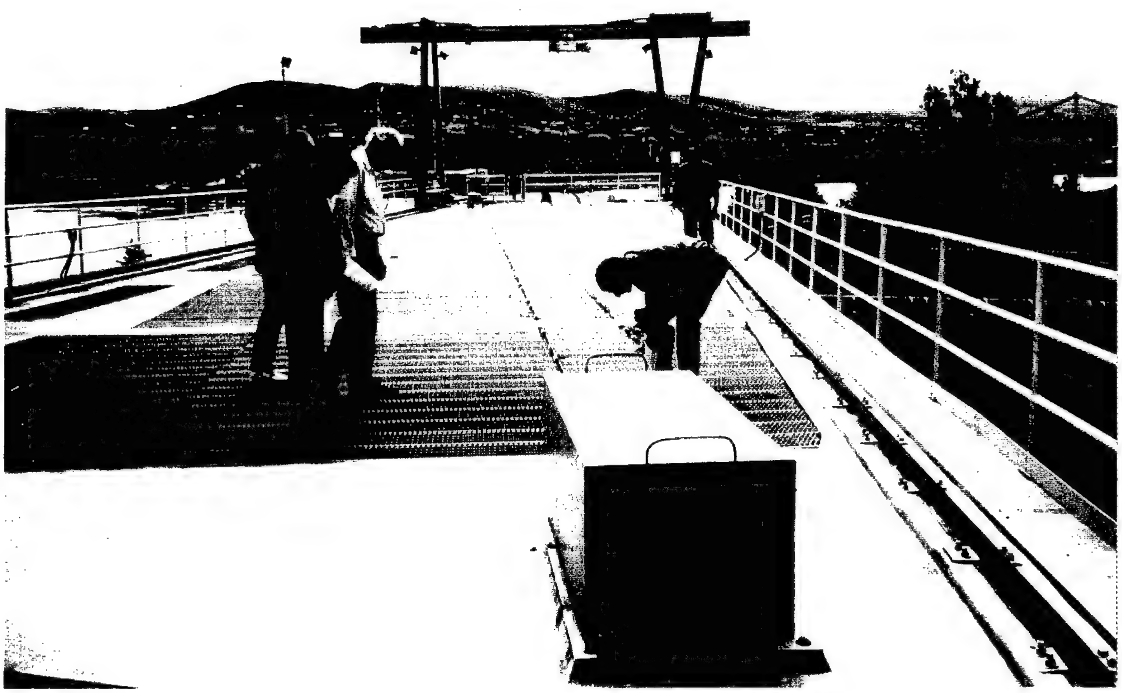
The main dewatering screen section is rectangular in shape with the screen bars mounted vertical and is cleaned using a horizontal traveling brush. The downstream sections of the screens are cleaned by brushes on a pivot arm, similar to a windshield wiper. The brushes appeared to work well with no reported maintenance problems.

Emergency Fish Bypass System

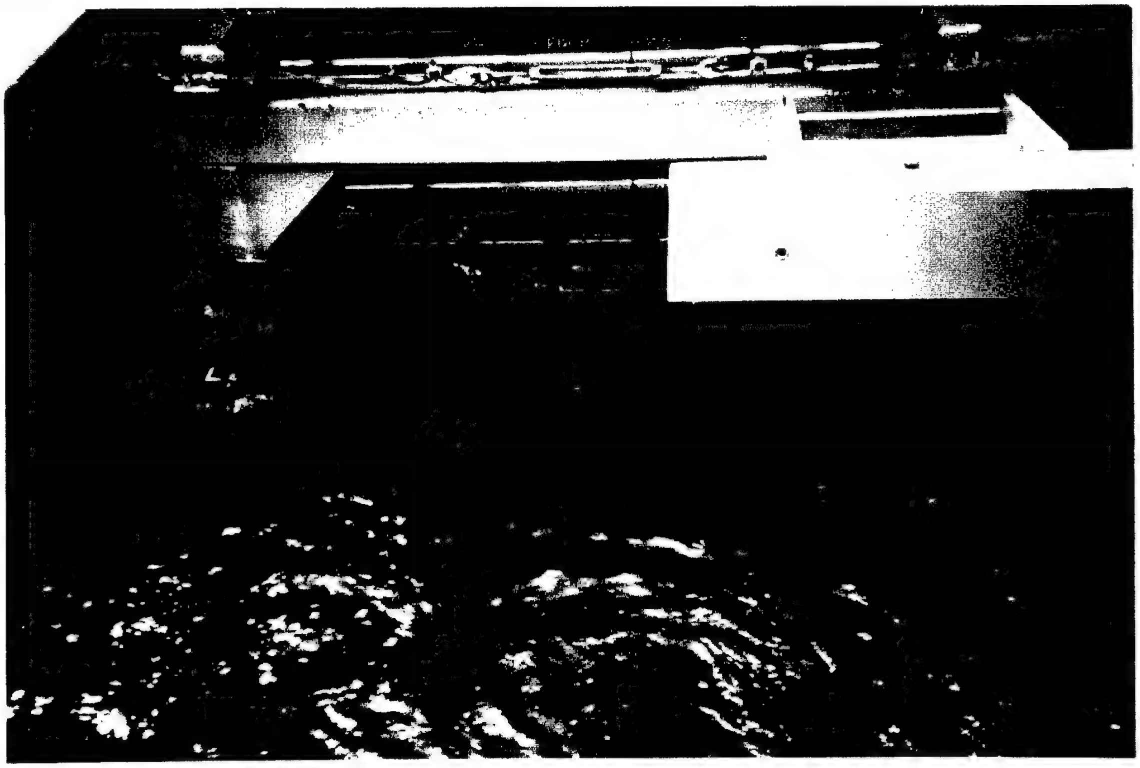
Should the turbine generator unit be off-line the attraction flow can be routed to the tailrace by sluice gates located upstream of the dewatering screens. Flow through the sluice gates drops into a plunge pool and is diverted to the tailrace via an excavated rock channel.



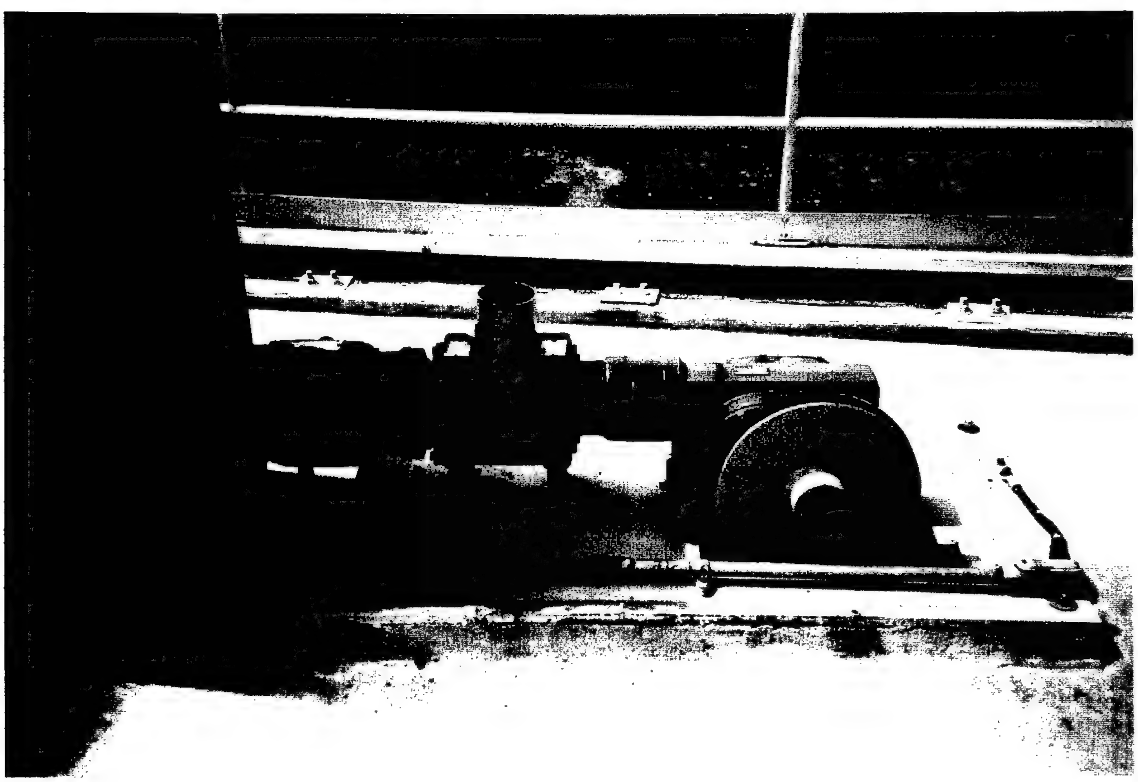
View of northshore fishway with penstock exiting structure to lower left. Note black bypass pipe exiting structure to left center of photo. The dam is to upper right with river behind photographer.



Downstream view of deck over fishway structure. Primary dewatering screens and porosity tubing follow the diagonal line in decking from photographer to downstream left of structure.



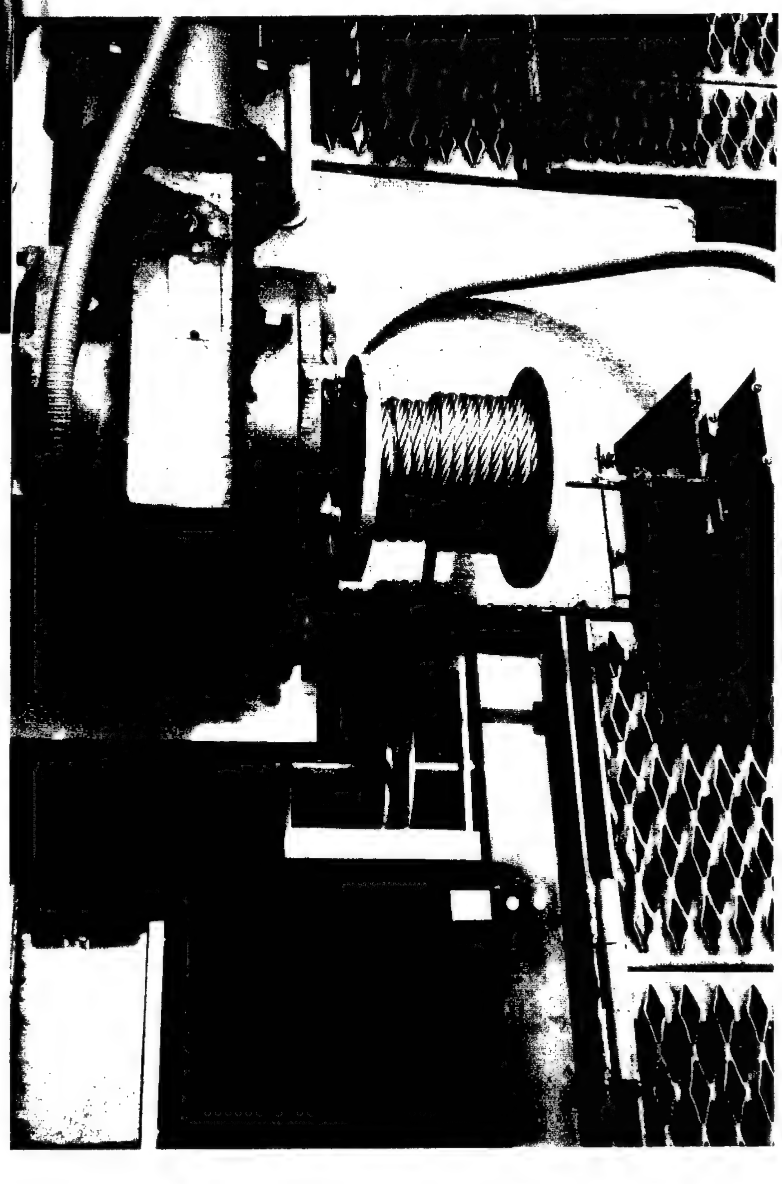
Screen cleaning system with vertically mounted brush traveling horizontally along rectangular sections of screens. Note counterweight in upper right of photo apply pressure between brush and screens.



Drive motor for horizontally traveling screen cleaning system.

THE DALLES DAM/NORTHERN WASCO COUNTY P.U.D.
Columbia River - Washington

"Wiper blade" type screen cleaning brush system to clean large triangular section of wall screens. Counterweight in upper center of photo to lower brush into position. Bar screen in left center of photo with 3"x8" tubing for porosity control behind screens to far left.



Motor and wire rope hoist for raising "wiper blade" type screen cleaning brush.

2.6 Rocky Reach Dam

General Project Description

Rocky Reach Dam is located 20.3 river miles upstream of Rock Island Dam at Columbia River mile 473.7 near Wenatchee, Washington. The dam crest is approximately 2,900 feet in length consisting of the gated spillway, the powerhouse, and a non-overflow concrete section on the right abutment. The powerhouse contains 11 generators with a total rated generating capacity of 1,240 megawatts (MW).

Lake Entiat is impounded by the dam extending 43 miles upstream with a surface area of 8,235 acres. The normal operating headwater pool varies between elevation 703 feet (minimum) and elevation 710 feet (maximum). Normal operating tailwater pool varies between elevation 607 feet (minimum) and elevation 612 feet (maximum). Average Columbia River flow at Rocky Reach Dam is about 100,000 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Rocky Reach developed a prototype surface attraction / bypass system for testing for the '95 season. The primary dewatering system is drafted by the Unit 1 turbine and the fishway attraction water through flap type control gates. The primary dewatering system was designed for 1,500 cfs and was dewatered to 100 cfs. The 100 cfs was reduced to 20 cfs through the secondary dewatering. The 20 cfs is routed through the dam and discharges 75 feet out in the powerhouse tailrace.

The intent of the design was to develop a temporary prototype structure with a design life of one year. The barriers were made of plywood and fabric supported on steel structural members and wire rope. It was recognized that testing may extend into a second year.

The configuration and location of the juvenile bypass was developed through analysis of field forebay hydraulics and fish distribution data and the use of a forebay physical model study. Studies showed that the hydraulics supplied strong fish guidance to the bypass intake location.

The original design included a Hypalon fabric falsework which improved the structures transitional geometry for deflecting flows into the bypass entrance. The hypalon falsework failed after two weeks of operation and was removed. The system is still operational without the falsework, and appears to still be effective. The major concern is trash, which is accumulating rapidly.

Dewatering Systems

The primary dewatering screens consist of slotted punch plate backed by larger orifice perforated plate. Perforated plate porosity varies from 30% to 60% and controls the through screen velocities. The porosity control was developed through physical modeling.

The method of cleaning the screens is with an Armstrong trash brush on a manually operated trolley. At the time of the visit, one of the two brushes was off-line, due to overload damage to the arm extension/retraction driver.

Emergency Fish Bypass System

In the event that the primary dewatering screening becomes fully plugged, the flow into the structure would be reduced to the flows which can pass over the primary dewatering system outlet weir. If the secondary dewatering system becomes plugged, the excess water will over flow the system and cause potential damage to the surrounding structures.

Fish Transportation System

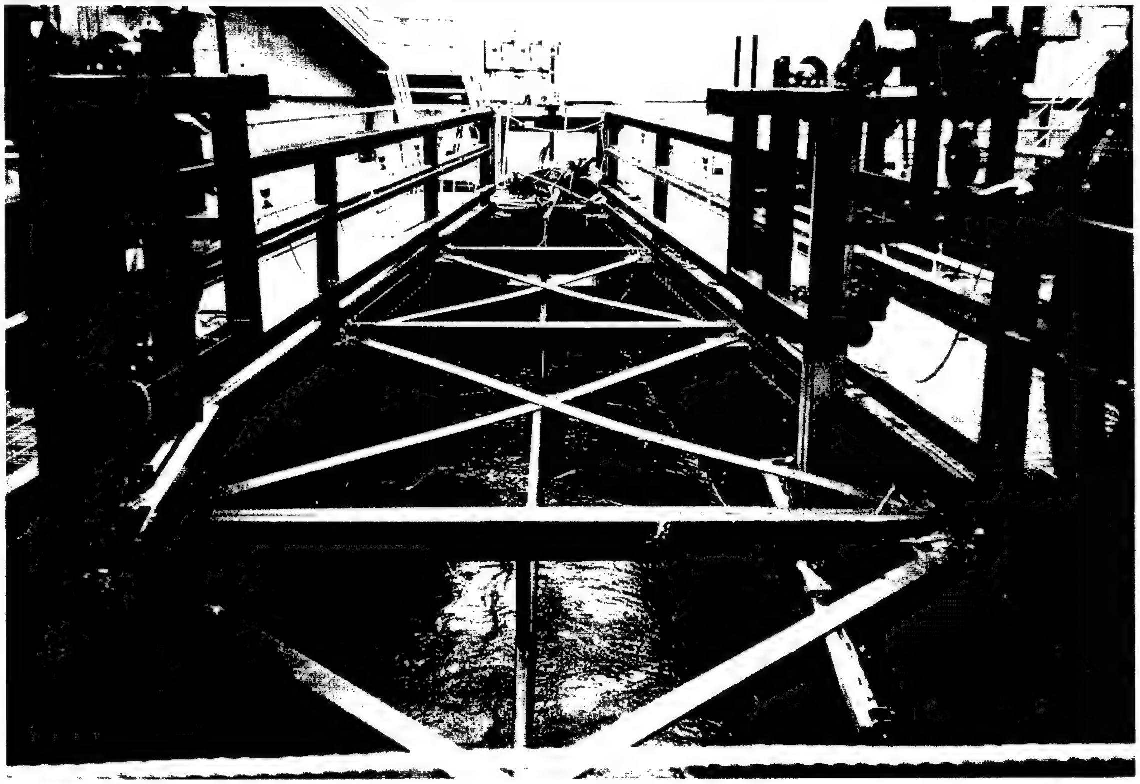
The bypass flow, 20 cfs, is routed through the dam via a circular conduit. The conduit transitions to a flume downstream of the dam to provide an observation point for counting fish passed. The flume transitions back to a pipe and is routed to discharge into the tailrace.

ROCKY REACH DAM
Columbia River - Washington

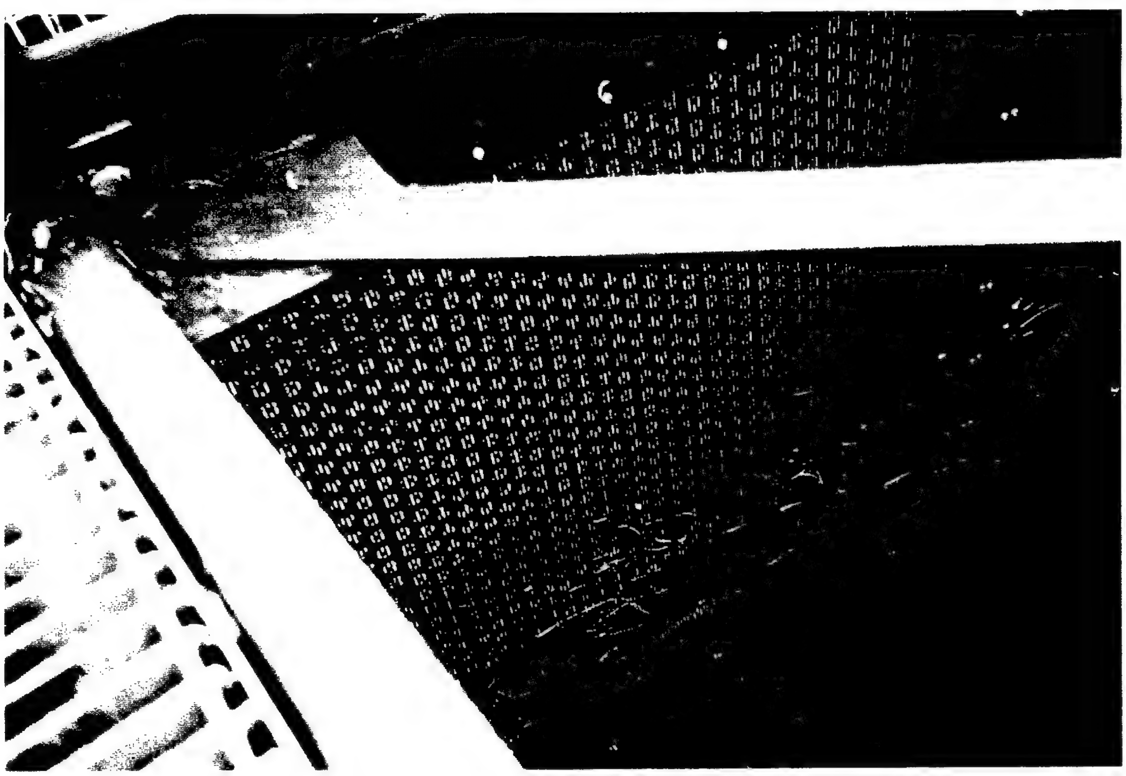
Overall view of surface bypass and collection system prototype with secondary dewatering (looking upstream) in lower center of photo. Fish entrance to system is in upper left of photo below gantry crane.

Upstream view of entrance channel and primary dewatering structure with center wall in channel for even flow distribution through screens. Dewatering discharge is drafted by powerhouse unit in upper right of photo using flap gates mounted in floor to throttle flow.

ROCKY REACH DAM
Columbia River - Washington



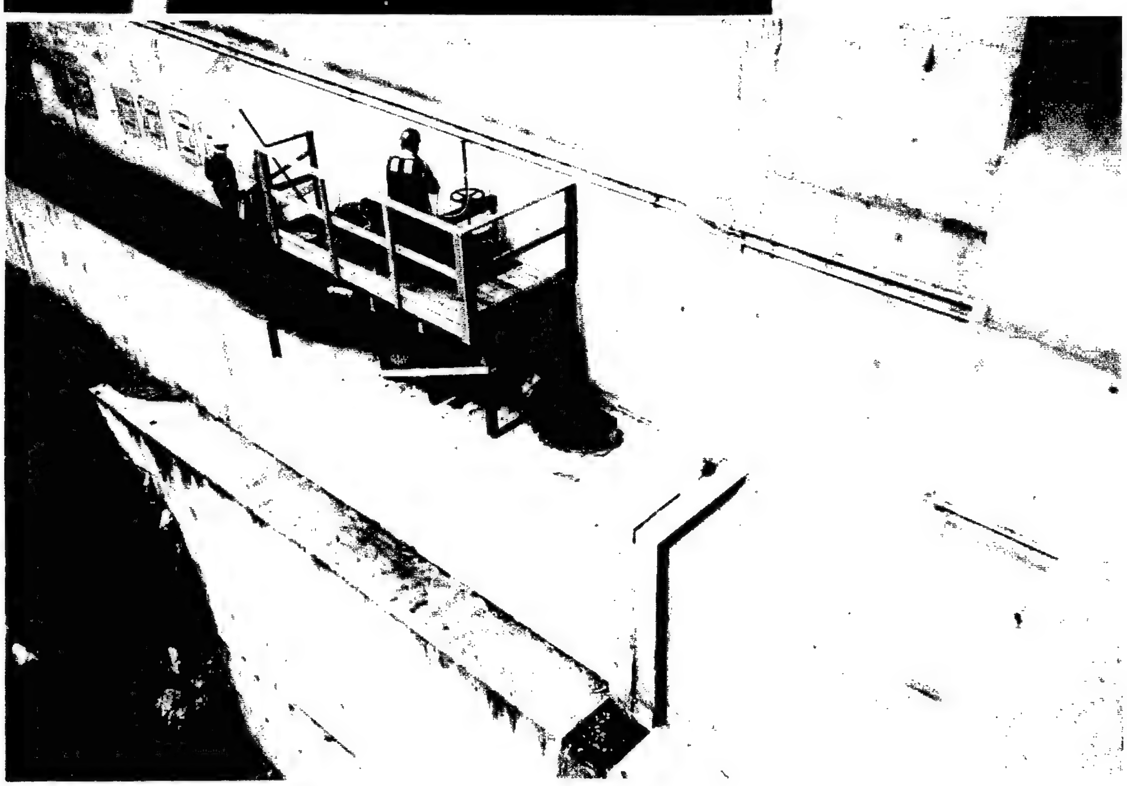
Downstream view in converging primary dewatering channel with brush systems on each wall. Note debris that has been removed on the deck in upper center of photo.



Slotted perforated plate on screening side of primary dewatering system with variable porosity circular perforated plate behind.

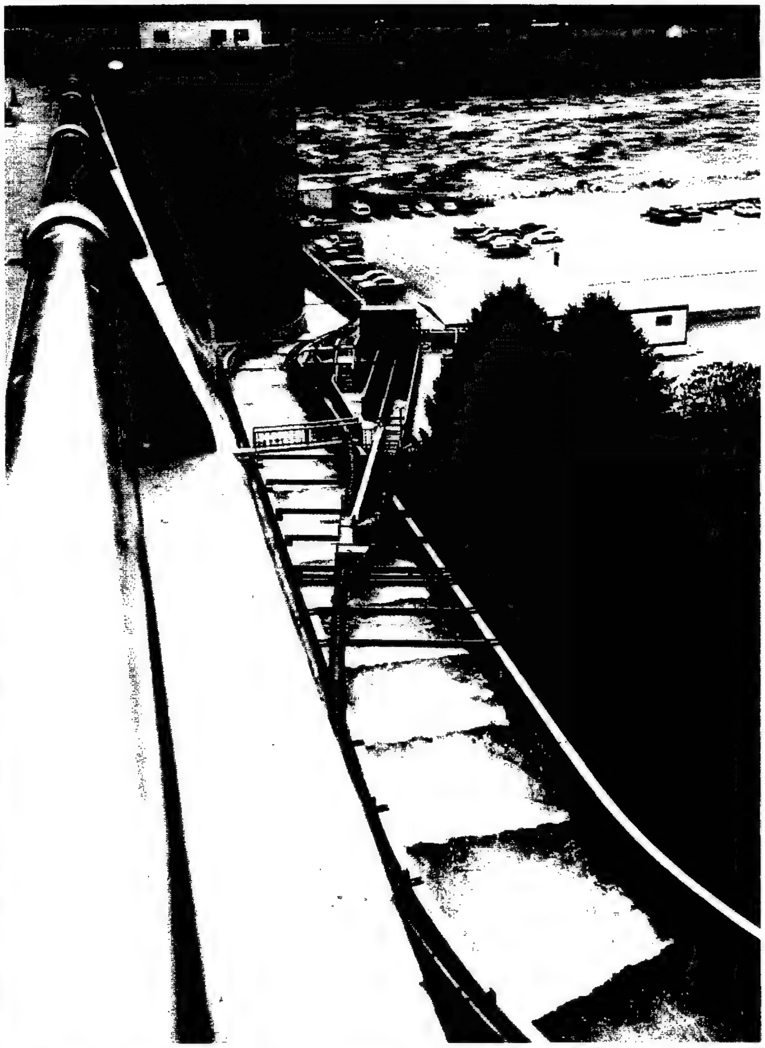
ROCKY REACH DAM
Columbia River - Washington

Downstream view of secondary dewatering channel. Note coarse trashrack in lower center of photo with grating above for cleaning personnel. Six weir gates in upper right of photo control removal of 80 cfs. Bypass discharge of 20 cfs continues through channel toward upper center of photo and into bypass pipe that passes through the dam.

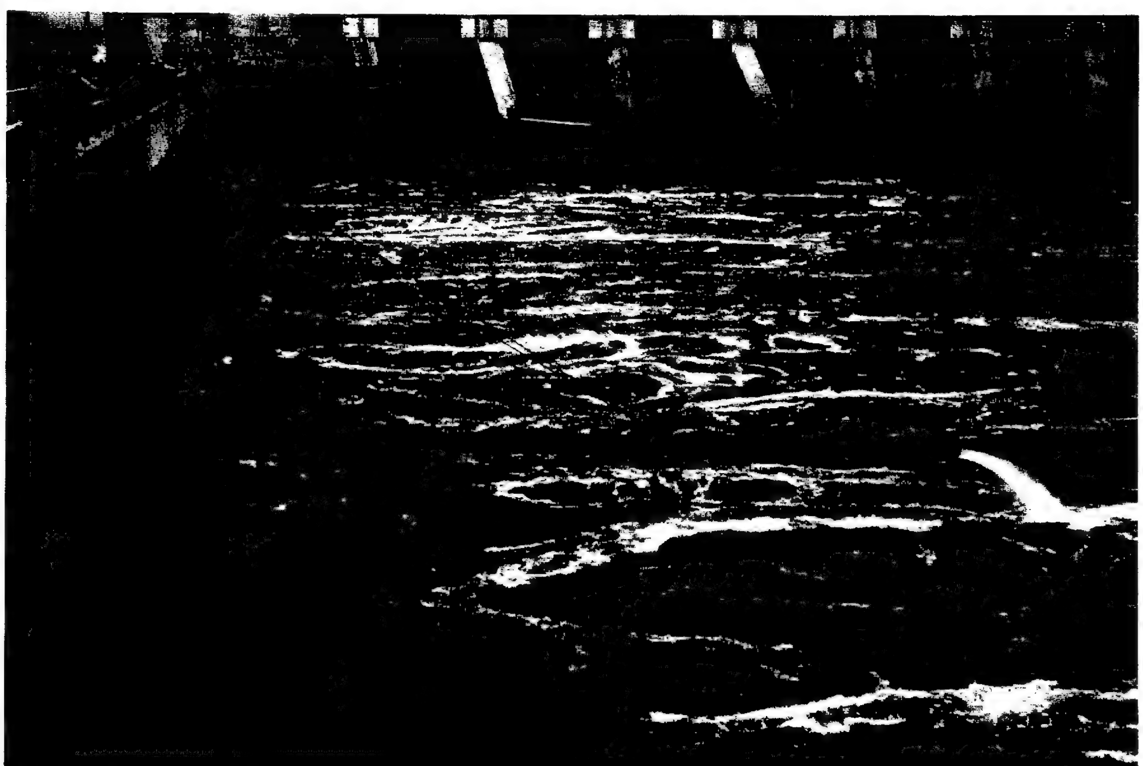


View of bypass pipe exiting dam on downstream side with valve to shut down the system.

ROCKY REACH DAM
Columbia River - Washington



View of bypass pipe mounted along fish ladder. Temporary fish handling facility adjacent to fish ladder. Bypass piping follows fish ladder downstream and exits in powerhouse tailrace.



Bypass pipe outfall near center of powerhouse approximately 75 feet out in tailrace.

2.7 Wanapum Dam

General Project Description

Wanapum Dam is located 18 river miles upstream of Priest Rapids Dam at Columbia River mile 415 near Vantage, Washington. The dam crest is approximately 8,537 feet in length consisting of approximately 5,750 feet of earth embankment, 424 feet of concrete gravity section, 1,000 feet of powerhouse, 540 feet of intake bays for future generating units, 823 feet of gated spillway, and two fish ladders. The powerhouse contains 10 generators with a total rated generating capacity of 831 megawatts (MW).

Wanapum Lake is impounded by the dam extending 36 miles upstream to Rock Island Dam. The normal operating headwater pool varies between elevation 560 feet (minimum) and elevation 570 feet (maximum). Normal operating tailwater pool varies between elevation 482 feet (minimum) and elevation 508.5 feet (maximum). Average Columbia River flow at Wanapum Dam is about 112,700 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Wanapum developed a prototype surface attraction/bypass system for testing for the '95 season. The dewatering system is drafted by sixteen (16) blower type axial flow submerged pumps. The water is diverted to Unit 10 or back to the headwater. The dewatering system was designed for 1,400 cfs and is dewatered to 500 cfs. The 500 cfs is routed through the dam, in a pressurized conduit, with the outfall in the spillway area.

Dewatering Systems

The screening material used is stainless steel perforated plate with 3/16-inch holes. Stainless steel was used since the project has experienced structural failures with painted mild steel plates in the past. The mode of failure appeared to be erosion of the holes, which weakened the plate, and lead to cracking of the plate. If the screens become plugged, only the flow which goes to the outfall will enter the intake. The blowers will then trip due to excessive differential between the intake and the area downstream of the screens.

A variable spaced bar arrangement is used to control porosity. Due to the good approach flow and screen geometry, a physical model study was not used in developing the design. The dewatering facility was patterned after the dewatering facility at Cowlitz Falls.

The problems experienced with trash at Wanapum are minimal. In addition, the intake for the surface bypass is submerged, and keeps most of the floating trash outside of the structure. There is no automated cleaning system at this time; cleaning is done by an operator with a broom. Pump reversal that generates back flushing is also proposed as a screen cleaning alternative.

Emergency Fish Bypass System

There are no provisions for an emergency bypass system incorporated into the Wanapum design. If the dewatering system is not functional the system is shut down and fish must pass over the spillway or through the turbines.

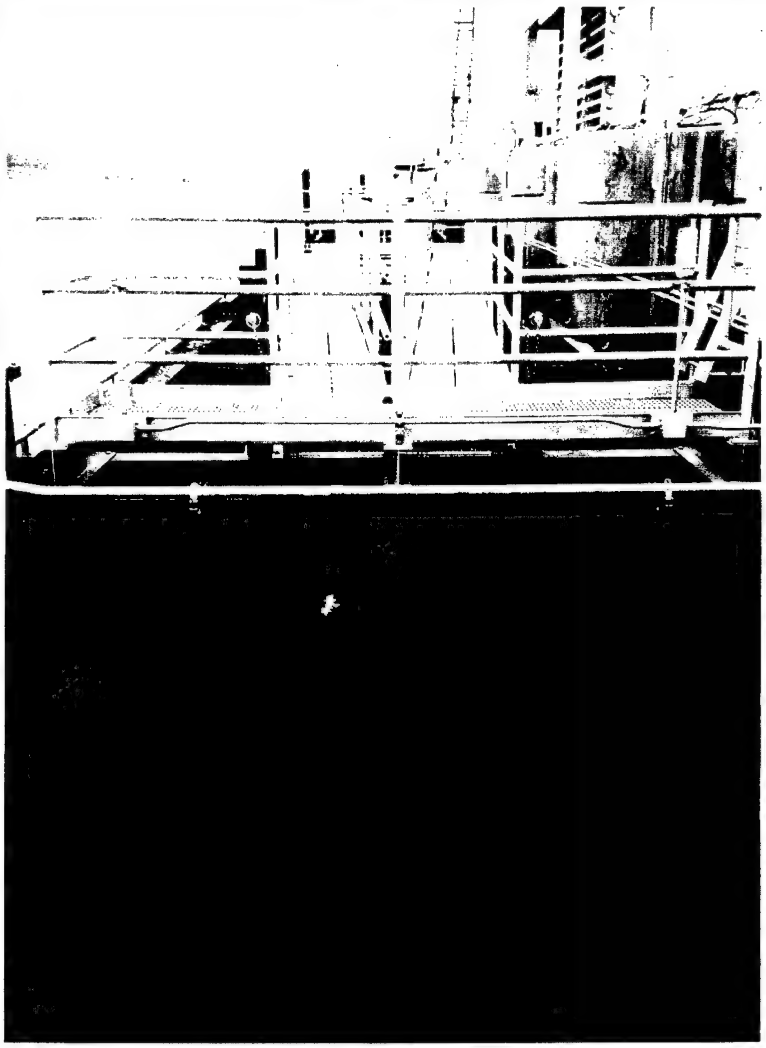
Fish Transportation System

Bypass flows are routed through the dam in a pressurized conduit. The conduit is routed along the downstream face of the powerhouse and follows the training wall which separates the spillway and powerhouse. The conduit discharges at the end of the training wall into the tailrace.

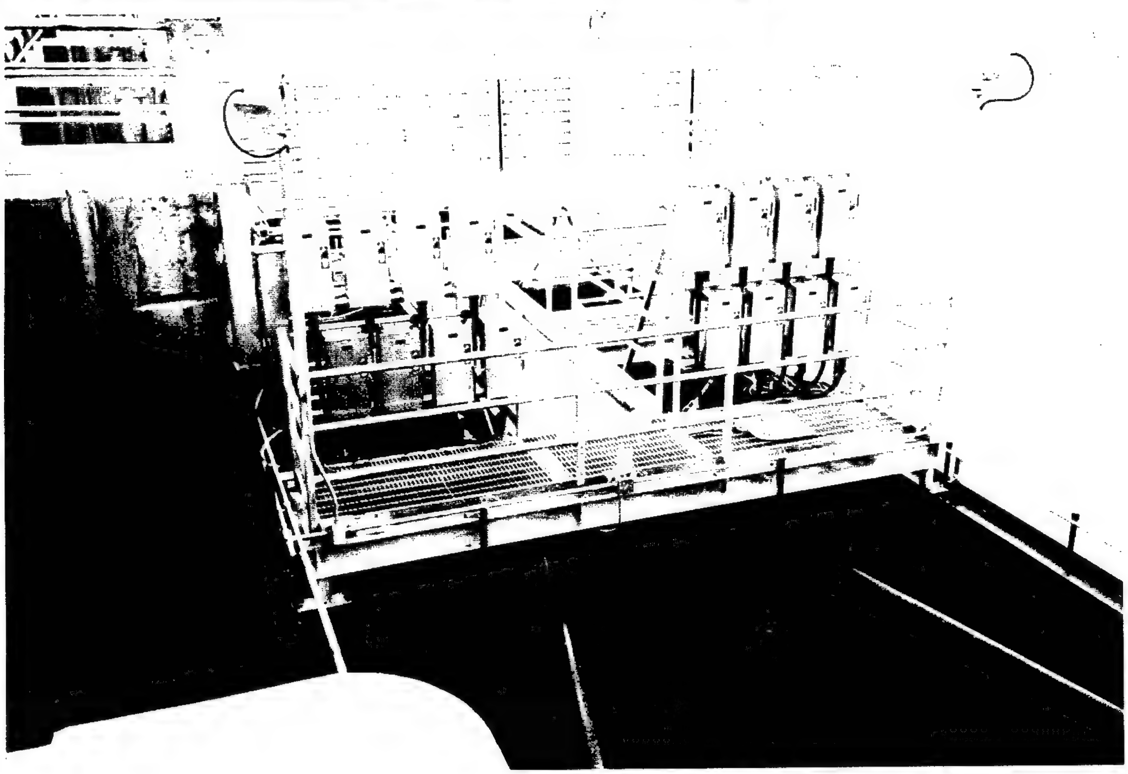
Downstream view of the collection/dewatering system with stainless steel perforated plate in converging walls beneath walkways. Coarse trashrack in lower center of photo. Control panels for blower pumps beyond

Bypass outfall piping (8-foot diameter) exits dam at end of powerhouse and discharges into tailrace. Bypass pipe discharge of approximately 500 cfs controlled by knife gate near the end of pipe.

WANAPUM DAM
Columbia River - Washington

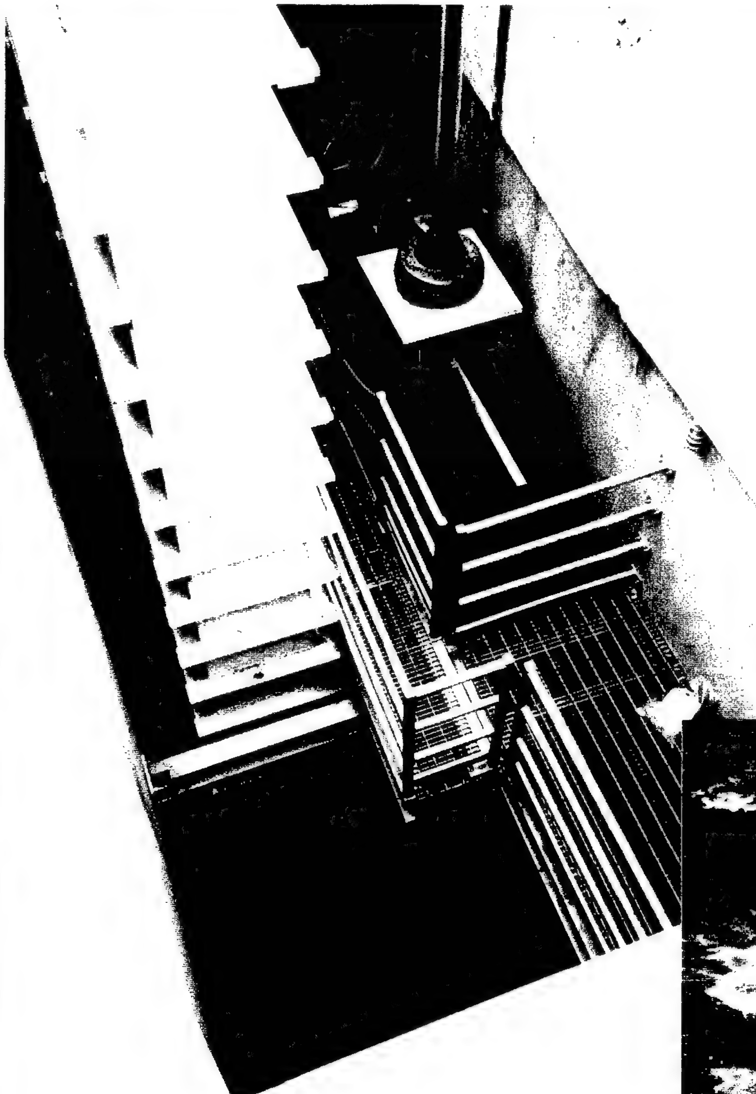


Upstream view of converging dewatering system with bypass pipe underwater in lower center of photo. Blower pumps draft discharge from outer channel sections toward bottom of photo.

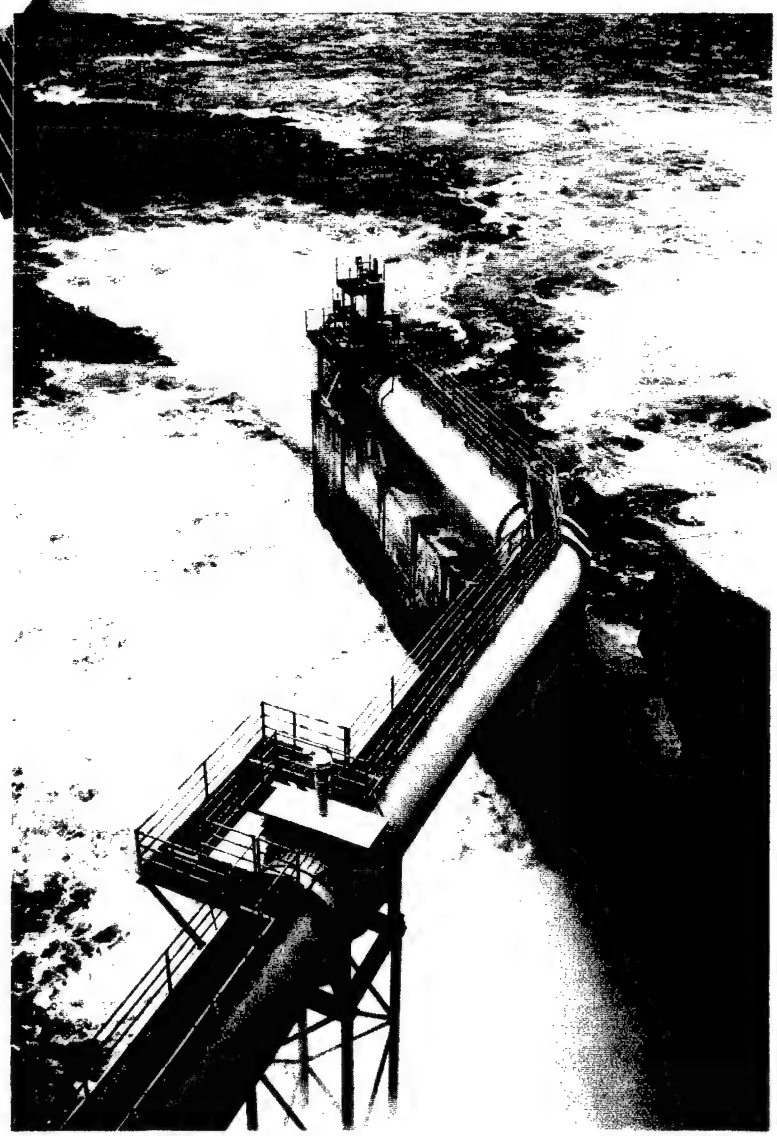


Blower pump control panels (eight on each side) at downstream end of prototype structure. Bypass piping (underwater) extends toward top of photo and turns 90 degrees left through the dam.

WANAPUM DAM
Columbia River - Washington



Bypass pipe emergency shut-off knife gate and air vent in gate well for future powerhouse unit. Bypass discharge from right to left.



Downstream view of bypass piping outfall between powerhouse and spillway. Control knife gate is at end of piping with an air release valve in lower center of photo.

2.8 Wapatox Canal Diversion

General Project Description

Wapatox Canal is located on the Naches River near Yakima, Washington. The primary purpose is to deliver water to be used for irrigation and power generation purposes. Maximum canal flow is about 500 cubic feet per second (cfs).

Description of Existing Juvenile Fish Facilities

Fish entering the canal through the intake are transported to the diversion system in the canal. They must pass through the control gate structure consisting of two radial gates. The regulated flow then passes through the trashracks into the dewatering system. The dewatering system reduces the flow from approximately 500 cfs to about 25 cfs. The bypassed flow downwells and transitions to a pipe which routes fish to the river.

The bypass system for routing flow around the dewatering structure operates as designed except during conditions in which icing is a problem. The maintenance staff has to manually break the ice and change flow conditions to keep ice moving through the system.

Dewatering Systems

The design is a single fixed "V" type vertical screening system converging from 38 feet wide at the upstream end to 4 feet wide at the downstream end. The downstream end of the dewatering section downwells and transitions to a 32 inch diameter conduit which discharges into the river.

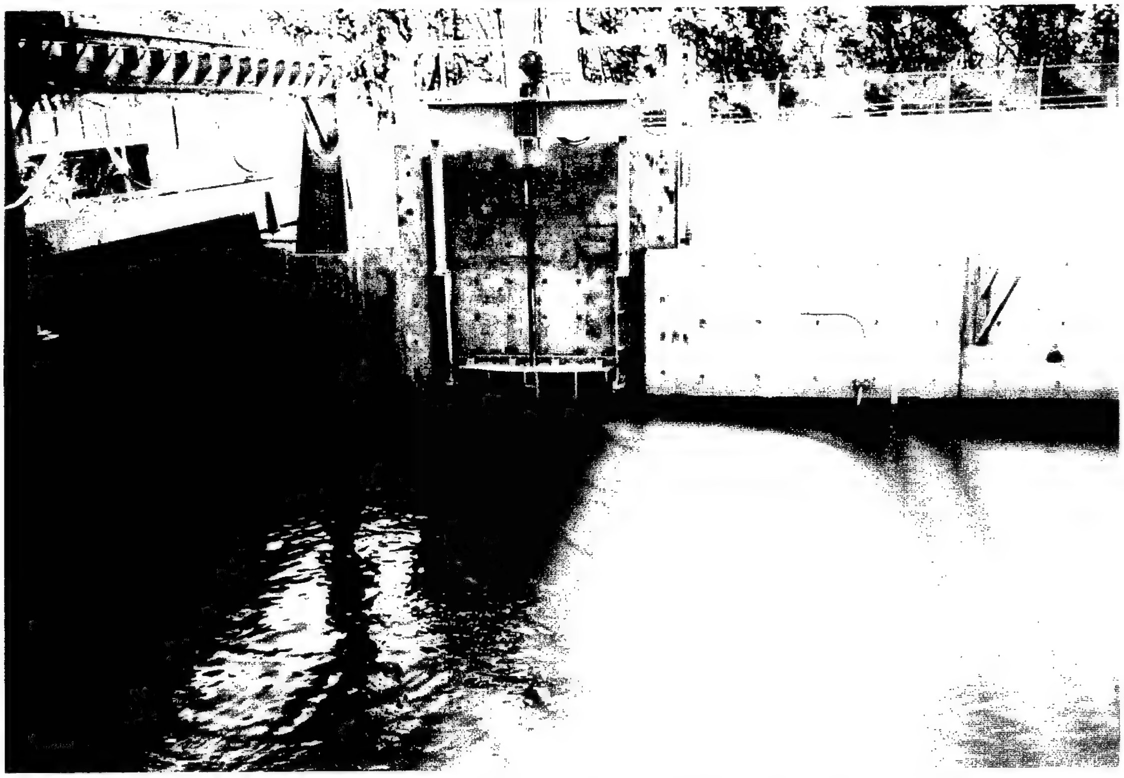
Stainless steel wedge-wire supplies the primary screen element. Porosity is controlled with adjustable vertical slats. The design was developed with the use of a physical model. Problems were noted with sediment accumulation and the inability to sluice ice and frazil ice during extreme cold periods.

The screens are cleaned by an Atlas hydraulic brush system. An arm with brushes attached is lowered into the water and a trolley drives the brushes to clean the screens. Debris removed by the brushes is routed through the bypass pipe back into the river. The system appeared to function well for debris removal, but becomes ineffective during icing conditions. Surface icing and frazil ice presents problems which have not been resolved as of the time of inspection.

Emergency Fish Bypass System

Sluice gates located on each side of the canal upstream of the trashracks are used to pass flow if the trashracks or dewatering system become inoperable. This system does not route fish back to the river, but is a means to continue to deliver water to the canal.

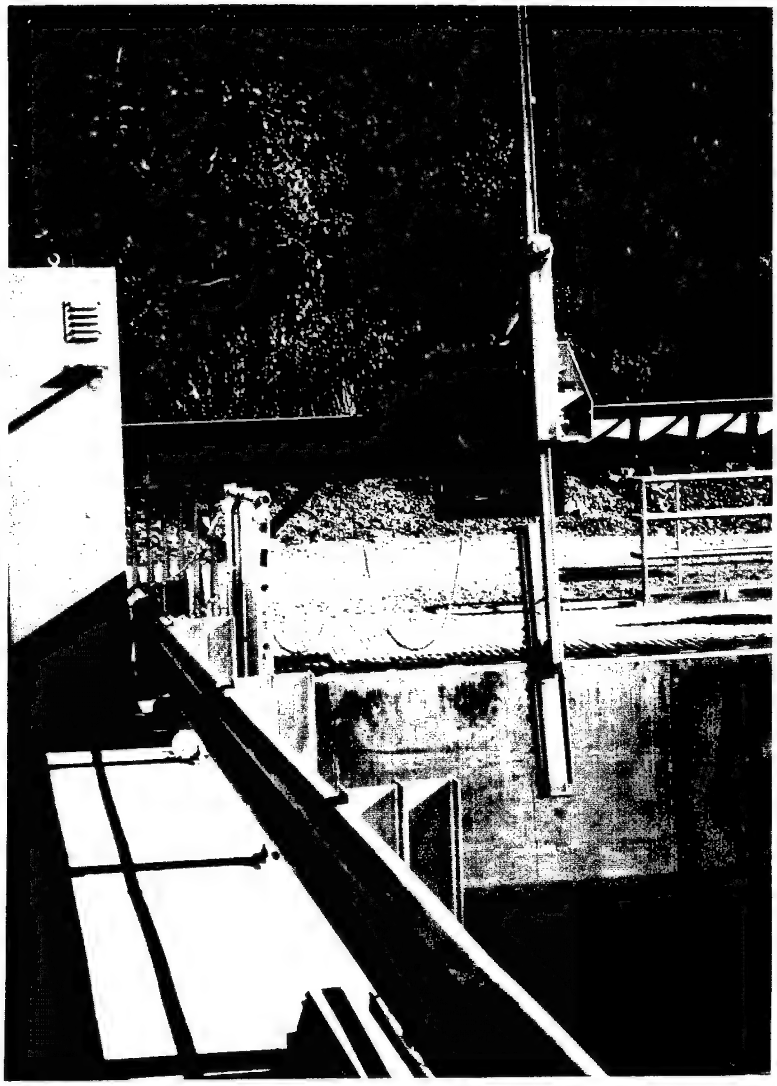
WAPATOX CANAL DIVERSION FISHWAY
Naches River - Washington



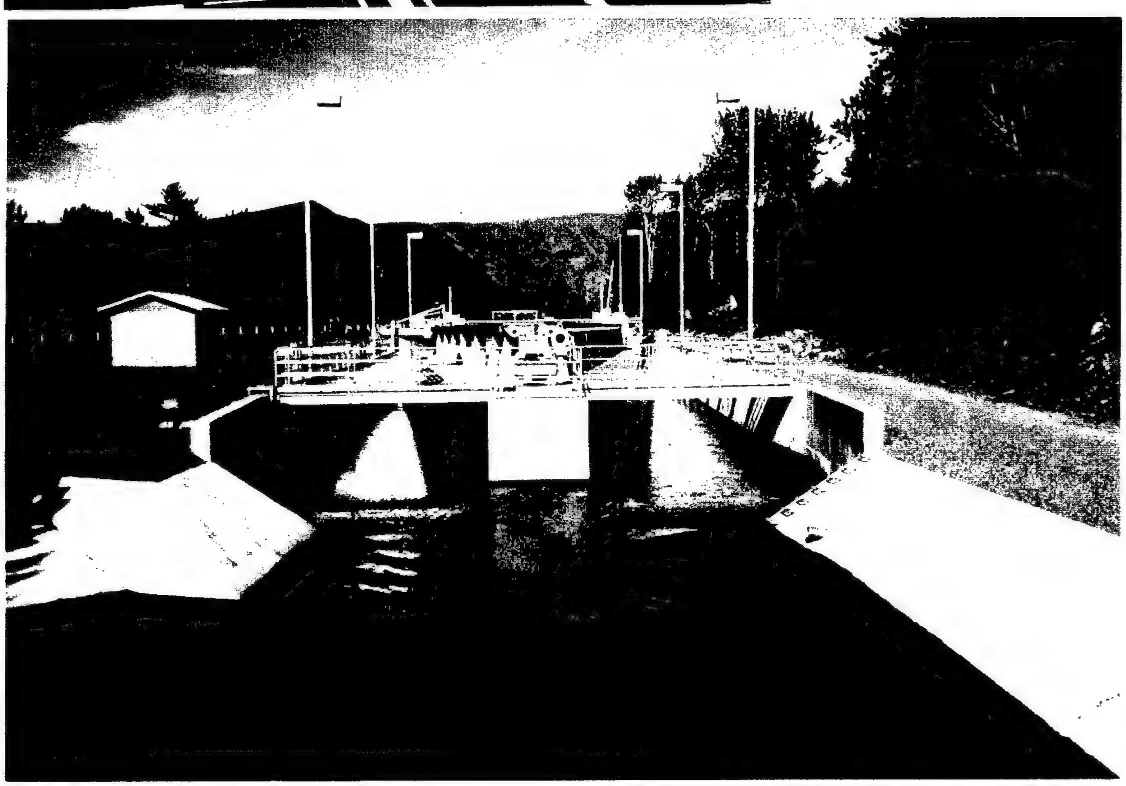
Diverted 500 cfs from Naches River flowing right to left into fishway structure. Trashrack in left of photo and emergency bypass gate in center of photo. Trashrake rail in upper left of photo.

Downstream view of converging screening facility with vertical screens and adjustable porosity vanes. Bypass piping with weir gate at downstream end of converging section. Screen cleaning system rails along converging section deck.

WAPATOX CANAL DIVERSION FISHWAY
Columbia River - Washington



Screen cleaning system with brush mounted on extending arm that travels along the rail via a chain and sprocket drive system.



Upstream view of screening facility with bypass piping extending from concrete box in center of photo underground and back to river toward left.

3.0 LITERATURE SEARCH FINDINGS

3.1 General

A literature search of the technology relating to dewatering system research, development, design, construction and operation was accomplished through: contacting Pacific Northwest Fish Agencies, Utilities, other A/E firms, Canadian projects and Corps of Engineers Portland District; and research of professional technical literature and technical society resources.

3.2 SWEC Project Files

During the past 10 years, Stone & Webster has done extensive work with EPRI on developing Research Projects on Fish Protection Technologies (See Summary No.s 1, 2, 3 & 4). In addition, many technical papers have been published. These references have been cited in the "List of All Documents Reviewed".

"Document Summaries" were prepared for four EPRI Documents and two papers on high velocity screens. These summaries can be found in Appendix C.

High velocity screens, such as the Eicher or the Modular Inclined Screen (MIS), were developed through extensive research conducted in conjunction with the Alden Laboratory and the Elwha Dam Project (See Summary No.s 9 & 10). The MIS was developed by SWEC while under contract to EPRI. The average survival ranged from 91.6% to 99.9% with a mean of 97.7%. The poorest survival rate was for Coho fry with an average length of 44 mm.

A SWEC designed prototype MIS facility is currently being assembled at Green Island (Niagara Mohawk Power) on the Hudson River, New York. This facility will begin operation and be evaluated in the immediate future.

The method of cleaning both the Eicher and MIS screens is by reversing the flow through the screens. The flow reversal is obtained by pivoting the screen in the conduit such that the bottom side of the screen is exposed to the flow path. During this short period, the fish can pass by the screen. Assuming a backwash cycle of once every 24 hours and a duration of 2 minutes, the percentage of time the fish are screened is 99.9%. At Puntledge, backflushes are conducted on a 4 hour interval. BC Hydro computes associated losses to 1.25%.

SWEC has also developed several Conceptual Options for the Rock Island Juvenile Bypass System (See Document No. 110). The overall dewatering system is similar to Little Goose, except the collection manifold is pressurized rather than open channel.

3.3 Electric Power Research Institute (EPRI) Documents

During the past ten years EPRI has done extensive work in summarizing all projects and papers relating to present and past fish protection technologies. The first document "Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application" published in 1986 (See Summary No. 1), evaluated effectiveness of existing protection systems, identified important biologic and engineering criteria, and preliminary concepts which warranted further research and development efforts.

The fish screening systems described and evaluated in this document for further R&D include: angled drum screens, angled fixed screens, inclined pressure screens, submerged traveling screens and gatewell systems. The majority of the research and development concepts for screening systems concentrated on screen types, screen orientation and debris removal.

Wedge-wire and wire mesh screens showed promise for diverting juvenile fish with little injury or mortality; and with the correct orientation, the screens were largely self-cleaning (See Document No.s 7, 9, 35, 132 & 139).

The most effective means of screen cleaning was found to be backflushing. A reversal of water flow through the screen for 10 seconds was sufficient to remove virtually all of the debris (See Document No. 150).

In 1994, EPRI published "Research Update on Fish Protection Technologies for Water Intakes" (See Summary No. 2). This update reviewed the research advances in fish protection technologies since EPRI's 1986 technology status report. The most significant advances were made in the development of high-velocity fish screens.

The National Marine Fisheries Service (NMFS) established a basis for screening criteria and factors to be considered in the design of screening facilities and bypasses (See Document No. 151). These criteria provide general guidelines for preliminary engineering and design of screening facilities. However, final criteria are set and approved by the agencies on a site by site basis.

Angled fixed screens have been installed by California Fish and Game at a large number of irrigation diversions in California. Most designs utilize perforated plate or wedge-wire screening material with mechanically driven brushes for debris management. Eugene Water and Electric Board (EWEB) installed the first large-scale angled screen facility at the Leaburg Hydroelectric project (EWEB, 1992).

Brush and air-burst cleaning systems are the most common and effective means of debris management currently in use. Automated brush systems have been installed at the Wapatox Canal Diversion and Dryden on the Wenachtee River (See Summary No. 2) and at the Corps of Engineers projects visited (McNary Dam, Little Goose Dam and Lower Monumental Dam). An air-burst cleaning system was installed at the Twin Falls Hydroelectric project in the summer

of 1990 (See Summary No. 5). The Leaburg angled screen facility is cleaned by an automated back spray system (EWEB, 1992).

In 1994, EPRI also published "Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application" which summarized the results of fish protection studies and provides guidance for designing, installing and maintaining effective installations.

A variety of low-velocity screening systems have been installed to divert fish at water intakes. These include angled drum screens, angled panel screens, inclined screens and cylindrical screens. At present low-velocity screening systems offer the only proven means for diverting very small (< 30 to 40 mm) fish. Many studies have demonstrated that a well-designed system causes little injury or mortality to the fish that are bypassed, but few studies have conclusively demonstrated a diversion efficiency exceeding 90 to 95%. The fate of non-recovered fish has rarely been quantified. These types of facilities are typically among the most costly of the available bypass options (See Summary No. 2).

The high-velocity screening systems described in detail in this document may provide a significant cost savings over low-velocity screening systems. Studies conducted to date at two full-scale applications of the Eicher Screen (for screening penstocks) and laboratory studies of the Modular Inclined Screen (MIS) (designed for any water intake) indicate equal or better effectiveness than low-velocity screening alternatives. The data indicate that both the Eicher screen and MIS options are capable of providing passage survival rates exceeding 99% at velocities up to 6 to 10 fps depending on the target species and size of fish (See Summary No. 4).

High-velocity screens, such as the Eicher Screen or Modular Inclined Screen (MIS), have had extensive research completed in conjunction with the Harris Hydraulics Laboratory, University of Washington (See Summary No. 18), Alden Research Laboratory (See Summary No.s 3 & 4) and the Elwha Dam Project (See Summary No. 10). General descriptions and guidance for MIS application has been developed through the above mentioned research (See Summary No.s 8 & 9).

Another 1994 EPRI report, "Biological Evaluation of a Modular Inclined Screen for Protecting Fish at Water Intakes" (See Summary No. 4), details the biological effectiveness of a standardized high-velocity fish screen design that can be adapted to most water intakes. The MIS is capable of protecting most species of fish at rates exceeding 99% over a wide range of approach velocities. The modular design resulted in a very uniform velocity distribution over the length of the screen without the need for baffles or changes in screen porosity.

3.4 Pacific Northwest Fisheries Agencies

Revised juvenile fish screening design criteria was approved by the Columbia Basin Fish and Wildlife Authority on February 15, 1995 as Regional screening criteria. Staff from the National Marine Fisheries Service, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and the Idaho Department of Fish and Game reviewed the criteria and their comments were incorporated. The criteria include site specific considerations including hydraulic conditions, weather generated influences, river stage-discharge relationships, sediment and debris problems, and the characteristics of the local fishery (anadromous, resident, predation potential). Structural placement, velocities, screen material, civil works and structure features, and bypass design are addressed. Key criteria for salmonid fry (less than 60 mm length) include approach velocities of no greater than 0.40 ft/s and screen openings not to exceed 2.38 mm for perforated plate, 2.38 mm (in the narrow direction) for woven screen and 1.75 mm slot width for profile bar screen. Fingerling (greater than 60 mm length) criteria is also presented which may be applied to the design if the absence of fry-size salmonids in the vicinity of the intake is documented. (See Summary No. 13)

It is generally recognized that the above criteria is conservative. However, it is also recognized that the conservative criteria insures effective screening even with the adverse influence of factors such as screen fouling, non-optimum water temperatures, variations in approach velocity distributions, variability in fish size, variability in fish stock sources, and variability of biological populations. (See Summary No. 13 and Document No. 170)

With respect to allowable approach velocity distributions, Ken Bates of the Washington Department of Fish and Wildlife notes in a 4/10/95 E-mail communication with Darryl Hayes of the California Department of Water Resources (we have had difficulty contacting Bates - P. Johnson had access to this information from his previous position with the Bureau of Reclamation) that:

> "The intent in Washington at least is not to exceed criteria velocity on any part of the screen. It's impossible though; screens are built with exactly the screen area required and no more. We have accepted velocity variances of 20% in small areas. It is difficult even in the most uniform and consistent situations to do better than that. We would not allow the approach velocity criteria to be exceeded adjacent to a bypass entrance however." (See Document No. 170)

Communication with S. Rainey indicates some willingness to consider higher velocity screens (Modular Inclined Screens or Eicher Screens). However, Rainey indicates that NMFS considers the higher velocity screens developmental and that they would prefer use of traditional criteria. Bates notes that the MIS/Eicher screens are dependent on high sweeping to approach velocity ratios (suggests possibly a minimum 4 to 1 ratio) to quickly guide fish past the screens, thus minimizing exposure time. He notes that use of higher velocity criteria likely should be tied to screen size and that development of such criteria would be worthwhile. He notes that "A migrating salmonid subjected briefly (several seconds?) to an intake surrounded by a sweeping

flow that is several multiples of the approach velocity and with an approach velocity still less than the fish's burst swimming speed should not be impinged or injured." (See Document No. 170 and personal communication with S. Rainey)

If a higher velocity criteria is pursued, the dewatering facility may fall under NMFS Experimental Fish Guidance Devices position statement. This statement requires for experimental technology:

(1) A thorough review of earlier research.

(2) Development of a study plan that considers the full range of possible hydraulic, biological, and ecological conditions that the device is expect to experience.

(3) Conducting laboratory experiments under controlled experiments using species, size, and life stages intended to be protected.

(4) Conducting prototype studies to (a) demonstrate performance at all expected operational and natural variables, (b) evaluate the species, or an acceptable surrogate, that would be exposed to the device under full operation, and (c) avoid unacceptable risk to depressed or listed stocks at the prototype locations.

If use of higher velocity criteria is pursued, the implications should be explored further with the resource agencies prior to substantive concept development. (See Document No. 64)

3.5 Area Public Utility Districts

Northern Wasco County PUD, The Dalles Lock and Dam

In 1991, The Northern Wasco County Peoples's Utility District installed a 5 MW turbine and a juvenile fish passage facility. The design and operations are discussed in Section 2.5, herein (See Document 69 & 120). It should be noted that the system was not designed to be a surface bypass /collection system (SBCS), but functions well as a SBCS.

Grant County PUD, Wanapum Dam

In 1993, Grant County Public Utility District developed five (5) options for a surface bypass system, of which three (3) options have a dewatering system (See Summary No. 6). In order to get a prototype system installed by Spring of 1995, Grant County choose to develop a different option which could be designed, fabricated and installed in the available time frame.

Much of the 1995 Wanapum surface bypass structure is a dewatering system. The dewatering structure screen includes angled vertical wall screens and an inclined floor screen. Porosity control in achieved using a bar system. The screen is drafted by axial flow blowers. The blowers are oriented such that the flow is parallel to the powerhouse intake. The bypass flow

of approximately 500 cfs, is high (See Summary No. 7 or Section 2.6, herein).

Grant County continued it's SBCS efforts by developing eleven (11) full-scale SBCS options for consideration following prototype testing. All options, except one (1) utilize dewatering systems. The options provided drafting for the dewatering screens by 1) a blower into the turbine, 2) a venturi arrangement into the turbine, 3) a blocked-out turbine bay, or 4) the spillway (See Summary No. 14).

Chelan County PUD, Rocky Reach Dam

The 1995 Rocky Reach surface bypass includes both a primary and secondary dewatering system. The primary dewatering system uses angled vertical wall screens with no floor screen. Porosity control is achieved using a perforated plate backing. The system is drafted by the powerhouse. The secondary dewatering system uses a vertical wall screen drafted by the powerhouse drainage systems (See Document No. 61 or Section 2.7, herein).

Pacific Power and Light, Wapatox Canal (Naches Hydroelectric Project)

In 1994, the Wapatox "V" configuration vertical wall screen bypass facility went on-line. The facility uses wedge-wire screen with adjustable louver porosity control. It has been performing well except for the handling of ice and frazil ice during periods of extreme cold. The design and operations are discussed in Section 2.8, herein (See Summary No. 2 & Document No. 119).

3.6 Corps of Engineers Portland District

The Green Peter collector and dewatering system has been operational since 1967. Even though the collector is largely inefficient and the bypass is in need of re-design, the dewatering facility reduces a 200 cfs flow to a bypass flow of approximately 10 cfs. The dewatering facility uses a circular bar screen (bars oriented parallel to the flow) with perforated plate porosity control. The facility was developed through use of a hydraulic model study (personal communication with Tony Norris). Details on fish exclusion performance and cleaning characteristics were not available as of this writing (Rock Peters will be contacted when he is available).

3.7 Bureau of Reclamation

Reclamation fish exclusion activities have traditionally focused on screening irrigation and power canals, largely at sites influenced by anadromous runs. Starting in the mid-1950's, Reclamation conducted development work on louver systems. Flume and prototype studies were conducted to develop a louver system for the Delta-Mendota Canal (Tracy Fish Facility), California. Louvers were pursued because of the relatively large discharge (4,600 cfs) and perceived cleaning problems associated with heavy debris loads. Hydraulic and louver array details were developed. The louvers were found to have guidance efficiencies in excess of 90% for 71-74 mm chinook salmon and 16-34 mm striped bass. Performance was found to be species and size dependent. (see Summary No. 1)

In the late 1960's and early 1970's, Reclamation actively supported the State of California in its Peripheral Canal studies. Based on a state-of-the-art review, screening options (including fixed screens and sand filters) that offered the potential for larval fish exclusion from the proposed 21,800 cfs diverted flow, were explored. Swimming endurance studies were conducted for Chinook salmon and American shad. Based on these studies, with relatively large data scatter, the State of California established its 0.33 ft/s normal component screening velocity criteria. Extensive fouling, cleaning, head loss, and corrosion studies were conducted on woven screens, wedge-wire screens, and perforated plate. Wedge-wire materials clearly showed the best self cleaning characteristics. Stainless steel screens showed best corrosion resistance with aluminum, coated and uncoated mild steel, and weathered steel showing considerably poorer performance. Brushing was found to offer the most effective cleaning mechanism for operating screens. (See Document No. 168)

In the mid-1970's, Reclamation explored fine mesh inclined screens (openings down to 0.2 mm) to prevent transbasin transport of undesirable fish, fish eggs, and fish larvae in association with the Garrison Project, North Dakota. Laboratory and field filtration efficiency, fouling, cleaning, and hydraulic characteristic studies were conducted. High copper content screen materials (monel and phosphor-bronze) were found to reduce growth on the screens. However, because of debris fouling, cleaning systems were required and consequently on-screen growth was not an issue. Back spray was found to offer effective cleaning for operating screens. (See Document No. 5)

Since the early 1980's, Reclamation has been actively screening diversions on the West Coast. Major screens (screened discharges of 1,200 to 3,000 cfs) developed include Tehama-Colusa, Chandler, Roza, Sunnyside, Easton, and Wapato. All of these structures are angled drum screens. Evaluation shows the screens to be effective with descaling rates of less than 2%. Screen seal and sediment removal maintenance may be required. Typically, cleaning (other than the normal self-cleaning that the rotating screen generates) is limited to a once a year spray wash. (See Summaries No. 1 and 2)

Smaller diversions are also being screened. Drum screens again have been largely used in the Yakima system. Wedge-wire cylinders with air burst back flushes have been effectively used at several locations. Reclamation, in conjunction with the State of California, is currently screening hundreds of small agricultural diversions (most less than 50 cfs) in the Sacramento-San Joaquin delta. Fixed vertical screens with continuous brush cleaners and wedge-wire cylinders with air-burst or water spray back washes are largely being used. Reclamation is also currently developing a fixed vertical multiple "V" wedge-wire screen for the 3,400 cfs Glen-Colusa Irrigation District diversion. Predator removal from the secondary screen facility at Tracy has been established as a routine maintenance operation.

Reclamation is currently developing a fixed horizontal modular screen concept. It is hoped that this concept will offer a reduced cost option for screening of small diversions. A physical model study was used to develop internal porosity or sink control to achieve uniform velocity distributions. Use of internal vanes to modify sink characteristics proved ineffective and

awkward. A variable porosity perforated plate was used effectively to generate an acceptable velocity distribution. Field testing of the concept is currently being pursued. Features including a cleaning system (a sequential air-burst system is being considered), installation details, and biological effectiveness are yet to be fully developed and evaluated. (Kubitschek 1995) Anticipated future Reclamation activities include the continued screening of diversions. It is anticipated that this activity will spread to non-anadromous sites with endangered species concerns. Reclamation is also actively pursuing an upgrade of the Tracy louver facility. Field development of higher velocity fixed screens that could be retrofit to the existing Tracy structure is being considered as an interim improvement.

3.8 Canadian Projects

As in the United States, fish exclusion priorities and perspectives vary by region. In the Maritime Provinces, outmigrant Atlantic salmon passage has been expedited through the use of surface collectors and bypasses. At a site on the Exploits River in Newfoundland, forebay hydraulics and configuration was noted to funnel smolt toward a gate that was used as a surface bypass. Likewise, floating skimmers have been successfully used to guide Atlantic salmon smolt to surface bypasses. (See Summary No. 15)

Similarly louvers are acceptable and have been used with success in the Maritimes. A louver structure configured in a single "V" located in the diversion canal of the Ruth Falls power plant on the East River, Sheet Harbour, Nova Scotia was evaluated as 85% efficient in excluding Atlantic salmon smolt. Recent successful guidance of Atlantic salmon smolt through use of a floating louver array at Holyoke on the Connecticut River reflects increased Canadian interest in the concept. (See Summary No. 15 and personal communication with C. Katopodis)

Ontario Hydro has an ongoing program to develop behavioral controls. The devices have been used to prevent entrainment or passage and to provide guidance and attraction at both thermal and hydropower stations. Extensive laboratory and field studies have been conducted using strobe lights, mercury vapor lights, and sound generators (pneumatic poppers, hammers, and transducer sound systems). Hybrid barriers including various combinations of these behavioral systems or use of light and/or sound in conjunction with hanging chains or bubble curtains have also been explored. Success varies with concept, hydraulic field, ambient background conditions, fish species, and fish size. Efficiencies of these devices vary from near zero to over 90 percent. Use of behavioral devices to improve attraction to surface collectors or to expedite passage through bypass or dewatering facilities is an option to be considered. (See Summaries No. 1 and 2 and Document No.169)

Screening has been pursued in Western Canada. Of particular note is the BC Hydro installation at its Puntledge Hydroelectric Project. At this site, a penstock was bifurcated allowing installation of two 10.5-foot diameter Eicher screens. The maximum approach velocity was 6.0 ft/s. A two year evaluation has been conducted. Total observed mortalities (initial plus 96 hour delayed) for coho and chinook smolt passage are less than 1.0 percent. Losses associated with back flush are computed at 1.25 percent. BC Hydro and the Canadian Department of Fisheries

(CDF) are both pleased with the screens performance. To date, maintenance requirements have been minimal. At this point, there is Canadian support of higher velocity screen concepts. BC Hydro is considering use of modular inclined screens at other sites. Berry Chillibeck of the CDF cautions that high velocity screens are considered behavioral devices. New installations will be treated as prototypes requiring site (and fishery) specific criteria, physical hydraulic model studies, and comprehensive field evaluation. (See Summary No. 2 and personal communication with B. Chillibeck and H. Smith)

Chillibeck and Katopodis indicate that nation wide screen design criteria is being developed. Efforts are directed at developing species and size specific criteria. Screen opening size will be based on design fish body dimensions. Velocity criteria will be based either on site specific swimming strength studies or on conservative envelope curves from existing swimming data. Drafts of the criteria should be released to the public by late summer or early fall 1995. (See personal communication with B. Chillibeck and C. Katopodis)

OVERVIEW OF DEWATERING SCREENS AT VARIOUS PROJECTS

Project Data			Dewatering Screens								
Name	Location	Owner / Contact	Operation	Geometry	Wedge-wire Orientation	Velocity Control	Flow Control	Type	Bar Size / Spacing	Gross Area	Screened Flow
McNary Dam	Columbia River Mile 292 Near Umatilla, OR	USACE - NPW Brad Eby (503) 922-4388	Primary Secondary	Floor Rect Floor Trap Side Rect Floor Trap Side Rect	Parallel Parallel Parallel Parallel N/A	Orifice Orifice Orifice	Slide gate Slide gate Slide gate Valve Weir	Wedge-wire Wedge-wire Wedge-wire Wedge-wire Perf-plate	1.75/2.0mm 1.75/2.0mm 1.75/2.0mm 1.75/2.0mm	1056 ft^2 146 ft^2 700 ft^2 52 ft^2	420 cfs w/ above 280 cfs 20 cfs 4 cfs
Lower Monumental Dam	Snake River Mile 42 Near Kahlotus, WA	USACE - NPW Bill Spurgeon (509) 547-7781	Primary Secondary	Floor Rect Floor Trap Side Rect	Parallel Parallel N/A	Baffle Baffle Perf-plate	Weir Weir Weir	Wedge-wire Wedge-wire Perf-plate	1.75/2.0mm 1.75/2.0mm	560 ft^2 50 ft^2	257 cfs w/ above
Little Goose Dam	Snake River Mile 70 Near Starbuck, WA	USACE - NPW Rex Baxter (509) 843-1493	Primary Secondary	Floor Rect Floor Trap Side Rect	Parallel Parallel N/A	Baffle Baffle Perf-plate	Weir Weir Weir	Wedge-wire Wedge-wire Perf-plate	1.75/2.0mm 1.75/2.0mm	477 ft^2 45 ft^2	210 cfs w/ above 5 cfs
Lower Granite Dam	Snake River Mile 107 Near Pullman, WA	USACE - NPW Tim Wicke (509) 843-1493	Primary Secondary	Floor Rect Floor Rect	N/A N/A	 Perf-plate	Slide gate Slide gate	Wire mesh Perf-plate	8 x8 1/4 in Ø	256 ft^2	210 cfs
The Dalles/ Wasco Co.	Columbia River Mile 192 Near The Dalles, OR	PUD-No. Wasco Co. Laurance Kerr (503)296-2886	Primary	Side Rect	Perpendicular	Var. Bar	Turbine	Wedge-wire		2450 ft^2	790 cfs
Wanapum Dam	Columbia River Mile 415 Near Vantage, WA	PUD #2-Grant Co. Steve Brown (509) 754-3541	Primary	Side Vee	Parallel	Var. Bar	Pumped	Perf-plate	3/16 in Ø	3025 ft^2	900 cfs
Rocky Reach Dam	Columbia River Mile 473.7 Near Wenatchee, WA	PUD #1-Chelan Co. Bill Christman (509) 663-1821	Primary Secondary	Side Vee	N/A	Perf-plate	Turbine	Slotted plate		1770 ft^2 0 ft^2	1400 cfs 80 cfs
Wapatox Canal Diversion	Naches River Near Yakima, WA	Pacific Power & Light (509)	Primary	Side Vee	Parallel	Var. Slat	Weir	Wedge-wire		1400 ft^2	475 cfs

4.0 FINDINGS, CRITERIA AND RECOMMENDATIONS

4.1 Screening for Juvenile Salmonids

All pertinent literature reviewed focused on two main concepts relating to dewatering facilities and components regardless of the type of screening medium used. The two concepts are; conventional "Low-velocity" screening and developmental "High-velocity" screening. Low-velocity screening is the most widely used and biologically accepted dewatering method used to date. In recent years, research and development efforts in high-velocity screening concepts have shown that this method may prove to be an acceptable alternative to conventional low-velocity methods.

4.1.1 Low Velocity Screening

<u>Findings</u>

The basis of low-velocity screening is to keep screen normal approach velocities below or near the long duration sustainable swimming velocity of the species and size of fish bypassed. Low normal approach velocities coupled with sweeping velocities, that guide fish across the screen face, minimize fish impingement and injury. Agencies recognize that screening criteria is site and species specific. However, general conservative guidelines have been developed to facilitate functional design and engineering. For salmonid fry (less than 60.0 mm length) maximum normal velocity criteria for low velocity screening is 0.4 feet per second over the gross screen area (National Marine Fisheries Service, 1995a). The fry criteria should be used in design unless the absence of fry and lack of adverse temperature conditions is verified (National Marine Fisheries Service, 1995a; personal communication with K. Bates, Washington Department of Fish and Wildlife). S. Rainey in personal communication indicates that with adequate documentation of the fishery, variances from the criteria have been allowed at some mainstem sites.

Low velocity screen concepts are widely used and widely proven. Although many low velocity screening concepts are cited in the literature (EPRI/SWEC, 1986; EPRI/SWEC, 1994a; ASCE Committee on Hydraulic Structures, 1981; and many others) for large surface collector dewatering facilities; functional, low velocity screening options appear to be limited. For screens designed to conventional criteria, the large screened discharges dictate large screen surface areas. The relatively deep (50 to 60 feet) surface collector intakes with near surface bypasses, conveniently accept screens that extend over the full vertical extent of the structure. Traveling screens do not fit well into the configured structures. Very likely either fixed wall screens or fixed wall screens in combination with fixed floor screens will be used. The current use of wall screens, with or without floor screens, reflects the general appropriateness of these screen concepts (CH2M Hill, 1994; Sverdrup Corporation, 1994b). Although screening options are limited, numerous features and variations are available. Features including screen medium, screen material, porosity control, sink control, cleaning, drafting mechanism, and dewatering

structure configuration should be addressed in development of the conceptual design.

Criteria

The dewatering system and screen designs shall be in accordance with the National Marine Fisheries Service Juvenile Fish Screening Criteria dated February 16, 1995. These criteria are summarized in the sections to which they apply:

- Guidelines apply to hydroelectric, irrigation, and other water withdrawal projects with site-specific waivers or modifications considered for extenuating circumstances.

- NMFS may require additional investigations at sites where site-specific variables are poorly defined.

- All designs must reflect NMFS design criteria and input, be acceptable to NMFS, properly function through the full range of hydraulic conditions, and account for debris and sedimentation conditions.

- **Approach Velocity:**

  - Limited to 0.4 fps for salmonid fry (less than 60 mm in length) assumed present at all sites.
  - Limited to 0.8 fps for salmonid fingerlings (60 mm and longer).
  - Required uniform flow distribution over the entire screen area.

- **Sweeping Velocity:**

  - Required to be greater than approach velocity.
  - Screen angle less than 45 degrees relative to flow.

Recommendations

Functional screening options are limited. Use fixed wall screens or fixed wall screens in conjunction with fixed floor screens designed to the National Marine Fisheries Service juvenile criteria revised February 16, 1995.

4.1.2 High Velocity Screening

Findings

High velocity screens (Eicher and Modular Inclined Screens) offer a relatively new screening concept that has recently undergone extensive laboratory and prototype development (Eicher, 1982; EPRI/SWEC 1994b). The concept of high velocity screening is based on maintaining high sweeping to normal velocity ratios that minimize fish impingement by quickly moving fish past

the screens even though the through-screen or normal velocities substantially exceed conventional criteria. High velocity screens depend, in part on a fish behavior of short duration burst avoidance of the screens to limit impingement.

Eicher screens at Puntledge Dam in British Columbia and Elwha Dam in Washington supply limited field verification of these concepts. A Modular Inclined Screen (MIS) will be installed and evaluated at Green Island, New York, later in 1995. The screens which are installed in rectangular or circular cross-section conduits, clean by pivoting and back-flush. Both biological and operational prototype performance, to date have been good. The screens have effectively screened 80 mm or longer steelhead, coho, and chinook smolt with total passage mortalities of less than 1.0 percent (EPRI/SWEC, 1994b; personal communication with Hugh Smith of BC Hydro). The screens have proven to be functional with low maintenance.

Because of the higher through screen velocities, required screen surface area, as compared to low velocity screens, is greatly reduced. As a consequence high velocity screens may supply a lower cost option. Although Steve Rainey of the National Marine Fisheries Service, in personal communication, recognizes the possibility of use of high velocity screens for dewatering; he also states his preference for the conventional criteria. Typically the resource agencies (National Marine Fisheries Service, Washington Department of Fish and Wildlife, Canadian Department of Fisheries) feel that even though the high velocity screens show potential, they are still developmental (Bates and Hayes, 1995; personal communication with B. Chillibeck of The Canadian Department of Fisheries). The resource agencies should be consulted before high velocity concepts are substantively pursued.

<u>Criteria</u>

High velocity screens are developmental. Standard, accepted design criteria are not available. Currently screens are designed based on site specific performance requirements as referenced to available prototype and laboratory study findings. The Elwha studies evaluated descaling and survival rates with penstock velocities ranging from 4.0 to 7.8 ft/s for steelhead, coho, and chinook smolts; coho, and chinook pre-smolts; and steelhead and coho fry (EPRI/SWEC, 1994b). Based on observed survival rates at Elwha and site specific head loss limitations, the Puntledge screens were designed for a maximum penstock velocity of 6.0 ft/s. Detailed laboratory hydraulic and fish passage studies of a 1:3.3 scale MIS model have been conducted with conduit velocities ranging from 2.0 to 10.0 ft/s. The Green Island installation will, in effect, be a 1:2 scale prototype field installation that will be evaluated at conduit velocities ranging from 2.0 to 8.0 ft/s.

<u>Recommendations</u>

High velocity screens should be condisered in conceptual design with evaluation of associated cost savings, performance uncertainies and verification requirements.

4.2 Screen Medium (Type)

<u>Findings</u>

Alternatives include use of perforated plate, wedge-wire, or woven screens. Based primarily on the California Peripheral Canal studies (Odenweller and Brown, 1982), wedge-wire is perceived to offer better self cleaning characteristics with minimal fish injury or descaling. 1994 biological testing of prototype vertical barrier screens at McNary Dam, however, show 6X6 polyester mesh to preform similarly to wedge-wire and suggested that for certain species the mesh actually yielded reduced fish injury/descaling. Through screen velocities for the McNary tests exceed NMFS FRP Criteria. Likewise mechanical cleaning was not used at McNary on the vertical barrier screens.

Based on experience at many sites both wedge-wire and perforated plate have been found to be durable when exposed to extended operation with physical cleaning using brushes. Wedge-wire is the most expensive of the alternative mediums. If the dewatering facility is designed to the relatively conservative fry velocity criteria (National Marine Fisheries Service, 1995a) which minimizes the potential for fish impingement, and if a cleaning mechanism is provided (which it likely will be); then self cleaning and descaling are not major issues and the benefits of use of wedge-wire are limited. Perforated plate offers a lower cost, functional medium which may be attractive considering the large screen surface areas required.

For high velocity screens, head loss across is sensitive to fouling (EPRI/SWEC, 1994b). Likewise, high velocities tend to exaggerate the potential for fish injury or descaling (EPRI/SWEC, 1994a; EPRI/SWEC, 1994b). Because of its good cleaning, fish handling, and durability characteristics, wedge-wire is the preferred medium for high velocity screen concepts.

<u>Criteria</u>

- **Screen Face Material:**

    - Salmonid fry assumed present at all sites unless proven otherwise requiring the following screen material criteria:

      Maximum perforated plate openings of 3/32 or 0.0938 inches (2.38 mm).
      Maximum bar screen openings of 0.0689 inches (1.75 mm).
      Maximum woven wire screen openings of 3/32 or 0.0938 inches (2.38 mm) in the narrowest direction.

- If salmonid fry are proven to be absent from site, the following screen material criteria may be used:

  Maximum perforated plate openings of 1/4 or 0.25 inches (6.35 mm).
  Maximum bar screen openings of 1/4 or 0.25 inches (6.35 mm).
  Maximum woven wire screen openings of 1/4 or 0.25 inches (6.35 mm) in the narrowest direction.

Recommendations

For low velocity dewatering facilities use perforated plate that complies with the National Marine Fisheries Service Juvenile Fish Screen Criteria revised February 16, 1995. Site specific variances from the NMFS criteria may be allowed based on documentation of the local fishery. For high velocity facilities, use wedge-wire as developed and verified with the specific screen concepts.

4.3 Screen Construction Materials

Findings

Fish screens have be fabricated from materials include stainless steel, mild steel (either coated or uncoated), aluminum, non-metallic, or high copper content alloys. Issues to consider in selection of an appropriate material include intended screen life, control of growth on screens, corrosion resistance, and abrasion resistance.

High copper content screens or screens coated with anti-fouling materials could be pursued if growth on the screens was a concern. With surface collector systems, however, the primary fouling source appears to be water transported debris. Use of most active cleaning systems, one of which likely will be included with dewatering facilities, would maintain clean screens and negate the need for control of growth on the screens.

Grant County PUD has found that mild steel experiences excessive corrosionwhich lead to perforated plate failure. As a consequence, Grant County PUD selected stainless steel perforated plate for the Wanapum prototype surface collector dewatering facility (personal communication with Steve Brown of Grant County PUD). Typically wedge-wire screens are also fabricated from stainless steel. The California Peripheral Canal studies show stainless steel to be a durable, low corrosion material. However, aluminum showed moderate corrosion while mild steel (both coated and uncoated) showed substantial corrosion (Odenweller and Brown, 1982).

Broad experience reflected in the site visits and in the literature demonstrate that metallic screens (in particular wedge-wire and perforated plate) are durable when exposed to extended cleaning with brush, back-spray, or air-burst systems.

Selection of an appropriate screen material depends on the desired screen life. For a permanent

installation use of stainless steel is recommended. For limited life prototype facilities use of aluminum or zinc coated mild steel may be options.

<u>Recommendations</u>

Selection of an appropriate screen material depends on the desired screen life. For a permanent installation use of type 304 stainless steel is recommended. For limited life prototype facilities use of aluminum or zinc coated mild steel may be options.

4.4 Porosity Control

<u>Findings</u>

Depending on the screen and sink (the screened flow outlet section from the dewatering facility) geometry, and their spacial relationship to each other, there will be a variation in the potential distribution across the screen surface and thus variation in through screen velocity distributions. Options available to adjust velocity distributions include locally restricting the flow path through the screen and thus locally reducing through screen velocities (porosity control) or modifying the sink characteristics in an attempt to generate a uniform potential field across the screen (sink control discussed below).

Porosity control options include using a fixed control that likely would be developed through use of a hydraulic model study. The model would be used to evaluate through screen velocity distributions and identify required porosity adjustments. Fixed porosity control, such as the perforated plate backing at Rocky Reach (Chelan County Public Utility District, 1995; CH2M Hill, 1994), offers the lowest cost option. This however may be offset by the cost and time associated with a hydraulic model study. Fixed porosity control likewise is not easily modified and thus adjustments for model/prototype variations or operational changes are not easily achieved.

Adjustable porosity control (such as the adjustable vertical louvers at Wapatox - note site visit documentation) when coupled with relatively simple screen and sink geometry may allow design without a model study. Note that more complex screen and sink geometries will generate three dimensional velocity distributions through the screen which will be difficult to adjust in the field. Two dimensional screen and sink arrangements like the "V" screen at Wapatox allow a good opportunity for field adjustment. Cost of field adjustable porosity control and cost of field adjustment may be significant.

Options for adjustable porosity control include rotating vertical louvers such as at Wapatox, vertical or horizontal stoplogs with spacers, and sliding/overlapping perforated plate. The Wapatox system was functional for that size of facility but may be difficult to use with 50 to 60 feet high sections. The specific fixed horizontal stoplog design (note site visit documentation) used at the Dalles Dam by the Northern Wasco County PUD is cumbersome and is not recommended.

Recommendations

If porosity control is selected to generate velocity distribution control, and if screen and sink geometry is anything other and a simple two dimensional arrangement; then a physical hydraulic model study should be conducted and fixed porosity control developed. If time is critical (insufficient time to conduct a model study), then screen and sink geometry should be simplified and adjustable porosity control supplied.

4.5 Sink Control

Findings

The sink or outlet section is the source of potential that draws flow through the screen. As noted above the interaction between the potential field that is generated by the sink and the screen surface, with influences from the flow field above the screen and secondary flow patterns, controls the through screen velocity distributions. By controlling the sink characteristics the potential field, and thus through screen velocity distributions, can be adjusted. Although not widely reported on in the literature, sink modification is widely used in the Northwest. Probably the best available document of screen/sink interaction is that by L.E. Cook, unknown.

By using multiple gates or weirs to draw off of a withdrawal pool (the discharge pool behind the screens), the sink can be spread over the length of the screen. Use of adjustable gates and weirs also allows local modification of the potential field. Depending on the extent of the withdrawal pool, such an approach may, however, continue to generate local high potential or high velocity "hot spots".

By using larger, low head loss withdrawal pools (losses across pool are small as compared to losses across the screen), local "hot spots" can be dampened and a uniform potential field can be created. Elements that create large head losses (as compared to other potential losses in the system) could also be inserted between the sink and the screens to create a uniform sink. Assuming then a relatively uniform potential field above the screens, a uniform differential across the screens with corresponding uniform through screen velocity distributions could be achieved. Such systems however may reduce the ability to locally compensate for velocity variations.

The screen and sink may also be segmented with walls or baffles which would allow for segmented adjustment of potential. Secondary flow patterns and local screen and sink geometry likely will however, likely continue to create local "hot spots".

All of the above options consume head which may limit, depending on concept and site, their application. Concepts using multiple gates or weirs may require a second, parallel, transport conduit. In general sink control uses more head and requires more structure than porosity control.

The advantage of sink control, if done correctly, is that it allows generation of relatively uniform through screen velocity fields without use of physical model studies or without awkward field adjustment of porosity controls. Likewise sink control offers more three dimensional velocity adjustment possibility than field adjustable porosity control.

As with porosity control, sink control can be either fixed or adjustable. Existing adjustable sink control (such as used on the secondary dewatering facility at Rocky Reach or on the dewatering facilities at McNary, Lower Monumental, or Little Goose - note site visit documentation) consist of gates or weirs off of the discharge pool. A clear advantage for this type of system is its convenience for field adjustment.

Recommendations

If a physical model study is not used to develop fixed porosity control, adjustable sink control should be considered as an option to adjustable porosity control. In particular, if screen or sink geometry is clearly three dimensional and a model study is not used, sink control is the best option for through screen velocity distribution control.

4.6 Cleaning

Findings

Fixed screen cleaning devices in use include air burst systems, back flush (pump back) systems, back spray systems, and brush systems. Use of effective cleaning systems is critical to sustaining effective screening. Poorly designed or ineffective cleaning systems (Leaburg-EPRI/SWEC, 1994a; Rocky Reach site visit) can yield debris roughened screen surfaces with elevated differentials and through screen velocities or loss of screening capacity.

Air burst cleaning systems are increasingly being applied to fixed, wedge-wire, floor screens. The concept, which is widely used and proven for cleaning cylindrical wedge-wire screens, uses the passage of large air bubbles up and through the screen to lift debris off of the screen surface and into the sweeping flow above the screen. The flow then carries the debris downstream and away. By sequentially cleaning from upstream to downstream, the full screen surface is cleaned. A screw type compressor with an accumulator tank is used to supply air to a series of orificed sparger pipes. Sequential operation is controlled using a programmed controller with solenoids. Frequency of cleaning can be controlled by timer or by monitoring differential or screen overflow. No moving parts or controls are submerged. Limited experience is currently available on floor screen cleaning. An air burst system has been effectively applied at the Twin Falls Hydroelectric Project (Ott and Jarret, 1991). Pacific Gas and Electric Company has conducted prototype studies to develop an air burst system for its Potter Valley intake. The Walla Walla District of the Corps of Engineers is exploring use of an air burst system on the dewatering facility at Lower Monumental Dam (note site visit documentation). Although not fully proven, it appears that air burst systems offer a low maintenance, effective cleaning alternative for floor screens.

Flow reversal back flushing is proposed for cleaning of the prototype dewatering screens at Wanapum. As of the early May visit, the pumps had not been reversed (the pumps must be removed and physically reversed) and back flushing had not been attempted (note site visit documentation). Flow reversal back flushing has been attempted with wedge-wire cylinders. The Delmarva Power and Light Company (Key and Miller, 1977) found that in an estuary setting, biofouling (direct growth on the stainless steel screens) generated the most stubborn cleaning problems. Flow reversal back flushing was routinely effective in cleaning the screens. However with time (two to three weeks during the high growth period), biofouling would increase head loss and in turn increase the detritus fouling rate. Flow reversal would not totally remove the biofouling. Consequently on a 21 day interval, the screens were removed and manually cleaned. Direct comparisons to biofouling in a Chesapeake Bay estuary are questionable. However the point should be noted that flow reversal back flushing will likely not effectively remove biofouling growth on low velocity screens. Back flushing in higher velocity flow fields such as with the Eicher screens (EPRI/SWEC, 1994b) and with gate well screens (Kcrma, et. al., unknown) has proven effective.

Back sprays have been effectively used to clean operating screens at a limited number of sites. Screens effective cleaned include a fixed inclined screen for the Bureau of Reclamation's Garrison Diversion (Johnson and Grabowski, 1980); conical screens at various Russian sites (Pavlov and Pakhorukov, 1974); and most noticeably the vertical, fixed, multiple "V" screens of the Eugene Water and Electric Board at their Leaburg facility (EPRI/SWEC, 1994a). At Leaburg, wedge-wire screen panels are effectively cleaned by a rotary spray backwash system. Cleaning is activated through monitoring of differential across the screen. The rotary spray does not fully cover the rectangular screen surfaces. Consequently, periodically screen panels must be pulled and pressure washed. Back spray cleaning does offer a cleaning option. Use of sprays, however, require use of either traveling screens past the spray or use of a traveling spray system.

The most widely used fixed screen cleaning systems use traveling brushes. The literature contains many references citing effective use of brush systems (EPRI/SWEC, 1986; EPRI/SWEC, 1994a). Likewise site visits showed broad use of brush systems (note site visit documentation). Brush systems typically track horizontally across the screen faces. The brush systems are generally effective on rectangular surfaces. Difficulty arises in maintaining effective tracking and cleaning on transition sections where section width is changing (note site visit documentation for McNary, Lower Monumental, Little Goose, and The Dalles/Northern Wasco).

As with spray systems, brush systems travel and require a supporting drive mechanism. Most sites, with the exception of Wanapum and Lower Granite, had a mechanical driver. It appears that the system used at Little Goose was the simplest and most reliable design for an inclined floor screen. The brush assembly is driven by a sprocket and conveyor chain on both sides of the channel. The submerged chain is covered to prevent potential damage to the fish. When the brush is not in use, it is stored above the water surface adjacent to the power train. The brush and power train are easily accessible for inspection and maintenance.

Wall screens, such as at Wapatox and Northern Wasco Co. PUD, are cleaned with a cantilever brush supported on a horizontal traveling trolley. At Wapatox the entire brush assembly, hydraulics, and driver are contained in an elevated commercially available unit, manufactured by Atlas Polar Company Limited, Toronto, Ontario. Similar equipment is manufactured by BIERI HYDRAULIK, Liebefeld Switzerland and Acme Engineering Co., Cordele, GA. The trolley travels on a light gauge rail with a conveyor chain and sprocket drive. A festoon system is provided to deliver electrical power. Limit switches are integral to the trolley with trigger stops mount on the rail system. Brush pressure and brush removal from the flow path is by hydraulic cylinders. The most significant advantage of the system is that it is easily accessible for inspection and maintenance.

The Northern Wasco Co. PUD cleaning system took the opposite approach to Wapatox. The power train is fixed and the trolley is moved by a friction cable. Brush pressure is obtained by a counter weight. The overall system is simpler than Wapatox but inspection an maintenance is more difficult. The brush remains in the water when stored, the trolley is below deck level, and the limit switches are at the end of travel. Due to the simpler design, maintenance should be less than Wapatox and provides a reasonable design for wall screen cleaning.

<u>Criteria</u>

- **Operations and Maintenance:**

  - Automatically cleaned as necessary.
  - Head differential to trigger cleaning shall be maximum of 0.1 feet.

<u>Recommendations</u>

Brush systems or brush systems used in conjunction with air burst systems (brush systems used with wall screens and air burst systems with floor screens) offers a generally proven and workable concept. The commercial (Atlas Polar or BIERI HYDRAULIK) type drives are recommended for use with the brush system.

4.7 Drafting Mechanism

<u>Findings</u>

An energy source must be tapped to drive the flow through the surface collector and dewatering system. Alternatives include:

1. Using axial flow pumps or blowers to return the screened flow from the dewatering system to the forebay.

2. Using gravity driven flow by discharging the screened flow from the dewatering system through the spillway.

3. Venting to a reduced pressure region in the penstock intake and thus passing the screened dewatering system flow through associated turbines.

Axial flow pumps are currently being used to drive flow through the prototype surface collector and dewatering system at Wanapum (Sverdrup Corporation, 1994b; site visit documentation). Discussion with Steve Brown, of Grant County PUD, indicates that although the pumped system is satisfactory, Grant County PUD would likely pursue turbine drafting for a permanent installation. Steve Rainey of the NMFS expressed concern that pumping may generate noise that will yield fish avoidance of the surface collector.

Discharging through the spillway yields loss of water and possible loss of generated power. Loss of spill capacity or adverse influence on reservoir control may also be issues.

Venting through the turbines is an attractive alternative. Possible drawbacks include a slight (approximately 0.2 to 0.5 foot) increase in penstock head loss, the limited head that can be created which may restrict the dewatering facility design, and a requirement that vented turbines be base loaded. To generate a significant venting differential, flow velocities in the venting region of the penstock intake likely must be increased. Since the most convenient venting location is at the trashracks, the potential exists that increased velocities will generate trashrack vibration.

Flow rate control is supplied with each of the alternative drafting mechanisms. Selection of the number of operating pumps (14 pumps total - 12 used at any one time at Wanapum) would be used with the pump back concept to control total flow rate. Gravity discharge through the spillway is controlled by the spillway gate. Venting to the penstock would be controlled by a gate on the venturi shroud drafting the penstock intake.

Maximum drawdown and differential loading on the dewatering structure could occur if the screens should plug as drafting continues. Drafting with the spillway, and to a lesser extent pumped drafting, have the potential to load the dewatering structure to failure. As a consequence, relief panels may be required with these drafting mechanisms. Because the drafting capability of the penstock intakes is limited by the velocity head, based on design details the maximum drafting differential is approximately 1.0 ft.

Recommendations

If possible, considering the above limitations, flow should be driven through the surface collector and dewatering facility by drafting on a turbine or turbines. If additional head is required or if base loading of an unit is not feasible, than pumping or discharging to the spillway offer options.

4.8 Configuration

Findings

The dewatering facility can take many configurations. Significant factors include screen geometry, sink geometry, drafting mechanism, schedule (time to conduct a hydraulic model study), cleaning, transition to existing bypass, and possible reuse of portions of existing facilities (such as the 1996 surface collector structure for Lower Granite). Many of these factors are site specific and at this point cannot be generalized. Configuration strongly influences both the effective functioning of the dewatering facility and the cost of the facility. Configuration selection requires creative design and offers substantial cost benefit.

Dewatering facility design should include identifying surface collector intake location, drafting locations, and bypass locations. Possible conduit configuration are thus established. Note that the flow distribution at the dewatering screens can be strongly influenced by the approach flow distribution which in turn is strongly influenced by surface collector intake location with respect to the screens and by the length and orientation of the approach conduit to the screens. It is difficult to correct poor flow distribution at the screens through use of either porosity or sink control. Care should be taken to establish good approach flow distribution (Johnson, 1988). Rocky reach and Wanapum supply good examples. With the Rocky Reach prototype surface collector the flow transitions directly from the forebay through the collector intake and into the dewatering screen section (Chelan County Public Utility District, 1995). Hydraulic model studies were used to establish a structure configuration that yielded good flow distribution. On the other hand with the Wanapum surface collector flow enters the conduit normal to the screen alignment. Sufficient conduit length however was included to allow establishment of adequate flow distribution at the dewatering screens (Sverdrup Corporation 1994a).

Containment structure configurations for the dewatering screens, possible sink locations, and possible screen configuration are then established. Configurations should be selected with consideration of the sink generated potential field, in an attempt to reduce required porosity or sink control. It should be established whether a hydraulic model study will be conducted. If a model study is not done, screen and sink configuration should be as simple as possible (preferably two dimensional). If a model study is conducted then configurations should be selected to minimize structure. Again the prototype facilities at Rocky Reach and Wanapum demonstrate the alternatives. Model studies were conducted for Rocky Reach and consequently screens were positioned to optimize transition from the collector (basically the collector and the screens are one). Variations in the through screen velocity field were corrected for through use of fixed porosity control developed using the model (Chelan County Public Utility District, 1995). Wanapum, however did not use a model study. As a consequence a long approach conduit was included in the design to establish an adequate approach flow distribution. The screens and sink were then symmetrically configured (Sverdrup Corporation, 1994a).

Drafting mechanism is also a major factor. In particular if the penstock is drafted, available head will be small. Designs should be pursued that establish acceptable velocity distributions

while minimizing losses. Again Rocky Reach with porosity control that minimizes head loss and a large cross-section (low velocity) conduit between the screens and the sink is a good example (Chelan County Public Utility District, 1995).

Desired methods for porosity and/or sink control and screen cleaning should also be identified. Porosity and sink control options will be appropriate for fairly specific structure and screen configurations and will limit dewatering facility configuration. With respect to cleaning, as Rocky Reach shows, addressing cleaning after the fact can be very awkward (note site visit documentation). Screens and structure should be configured with cleaning in mind.

With the above influences in mind, structure optimization and cost become major factors. Various structure configurations should be developed and cost evaluated. Through creative engineering, an effective site and structure specific facility can then be developed.

Criteria

- **Structure Placement:**

  - In rivers, desirable for screen face parallel to river flow.
  - In rivers, desirable for screen location at intake or have return transportation facilities.
  - In reservoirs, desirable for intake location offshore with allowable approach velocities.
  - In reservoirs, screened intake diversion should provide most appropriate juvenile attraction and water temperature.

- **Civil Works and Structural Features:**

  - Screen surfaces shall be placed flush with adjacent screen bay, pier noses, and walls.
  - Screens shall be protected from large debris.
  - Screen surfaces shall be constructed at an angle to the incoming flow.
  - Features designed to eliminate undesirable hydraulic effects.

- **Bypass Layout:**

  - Geometry such that out-migrating juveniles pass through the system without delay and with access for cleaning.

- **Bypass Entrance:**

  - Each entrance must have independent hydraulic control, ambient lighting available, and accelerating velocity into bypass to minimize delay.

- **Bypass Conduit Design:**

  - Smooth surfaces and joints required with minimal turbulence.
  - No pumping, free-fall, negative pressure, or sharp bends are allowed.
  - Design to minimize debris clogging and sediment deposition.
  - No closure valve allowed without special approval.
  - Minimum depth of 0.75 feet and no hydraulic jump allowed.

- **Bypass Outfall:**

  - Outfall in ambient river velocities greater than 4 fps.
  - Minimize predation potential.
  - Maximum outfall velocity shall be less than 25 fps.
  - Design to avoid adult attraction.

- **Modified Criteria for Small Screens:**

  - Screens <4 feet long may be normal to the flow.
  - Screens >4 feet long must be angled at less than 45 degrees to the flow.
  - Drum screens shall be submerged 75%.

Recommendations

The dewatering facility can take many configurations. Significant factors include establishment of approach flow distribution, screen geometry, sink geometry, drafting mechanism, schedule (time to conduct a hydraulic model study), cleaning, transition to existing bypass, and possible reuse of portions of existing facilities (such as the 1996 surface collector structure for Lower Granite). Many of these factors are site specific and at this point cannot be generalized. Configuration strongly influences both the effective functioning of the dewatering facility and the cost of the facility. Configuration selection requires creative design and offers substantial cost benefit. With respect to Lower Granite, development of the dewatering facility configuration is a major future task of this design effort.

4.9 Recommendations for Existing Projects

The following recommendations for existing projects are provided to:

- improve operations,
- reduce maintenance time and expenditures,
- minimize down time, and
- simplify control logic.

Lower Granite Lock and Dam

A. The Lower Granite upwell and dewatering system appeared to operate extremely well, considering there is no cleaning system. The higher normal and sweeping velocities appear to help keep the screens clean. The higher velocities do not meet the current Agency low-velocity screening criteria. However, they are well within the allowable velocities for high velocity screens, such as the Eicher Screen or the Modular Inclined Screen (MIS).

Little Goose Lock and Dam

A. The brush cleaning system at Little Goose appears to be the most effective of all the sites visited. The chain and sprocket arrangement provides a positive means of driving the brush and keeping the screens clean. This site was not visited when the system was on-line.

B. Investigation of an air-burst cleaning system to compliment the brush system is recommended in case of high debris loading.

Lower Monumental Lock and Dam

A. The dewatering system works well. Operation of the inclined floor screen brushes appears to be effective, however, the driving mechanism appears to be a weak link. The original design was a driver to the trolley wheels. The wheels were reported to slip and could not over come the hydraulic forces on the brushes. The current driving mechanism is by a wire rope wrapped around a friction drum. The pre-load tension on the wire rope is high in order to have adequate friction on the drum to drive the trolley. During operation, the wire rope crowds to one side of the drum and the rope passes over itself with a shape bend. When the drum reverses, the rope drifts to the opposite side, and the shape bend is in the opposite direction. Due to the high bending stresses and the high pre-load tension, the wire rope's life is limited.

   Consideration should be given to modifying the drive system. One option would be to use a conveyor chain and sprocket, similar to that at Wapatox. A second option would utilize a 3/4 wrap around a rubber line sheave, similar to Wasco.

B. The dewatering in the porosity control area, just upstream from the fish separator, appears excessive. In some areas, the screen draws air, which results in dry spots. Consideration should be given to replacing the wedge wire screen with perforated plate, similar to the arrangement at Lower Granite.

C. Emergency diversion screens were installed last winter ('95) in the dewatering channels. These screens were intended to prevent fish from entering the service water system in the event the screens plug and the channel overflows. The screens were installed hinged on one end, which allows the screen to float. The screen orientation appears to trap debris, rather than allowing it to pass to the tailwater. The functionality and design of the emergency diversion screens should be reviewed to determine if they operate as intended.

McNary Lock and Dam

A. The dewatering system works well. Operation of the inclined floor screen cleaning system appears to be effective. At the time of the inspection, the side wall dewatering system screen cleaning system was off-line. The primary driver gear box was reported as failed.

B. The geometry requirements for the side wall brush system is similar to the side wall screens at Northern Wasco County, PUD at the Dalles Lock and Dam. The Wasco brush is driven by a wire rope over a friction sheave. The brush engagement is driven by an off-set counter weight. The system was reported as working well and may be considered for application at McNary.

C. The control gates for the dewatering system provide a free discharge into a drop well. This approach puts excessive loading on the gates and causes a continuous mist to form in the area. Consideration should be given to pressuring the drop well and providing a turbine near the tailrace for energy dissipation. This will reduce the hydraulic loading on the gates and eliminate the mist.

D. Investigation of an air-burst cleaning system to compliment the brush system is recommended in case of high debris loading.

Northern Wasco County PUD/The Dalles Lock and Dam

A. The Wasco dewatering system appears to function as a SBCS. However, a few operational problems were observed. A continuous vortex exists above the penstock inlet. This condition appears to cause water surface drawdown which increases the differential head across the downstream end of the screen. To address this problem, the porosity control behind the screen have been eliminated in the upper reaches and are set at their minimum opening in the lower reaches. Even after the adjustments, the velocity through the screen is approximately 50% higher at the lower end than at the start of the

structure. Vortex generated air entrainment, with air passage thought the turbine does not appear to cause rough turbine operation.

B. The brush and trolley drive system appears to work well. The only reported problem was the need for a high pre-load tension on the drive wire rope. Consideration should be given to installing a tensioning spring which would absorb the changes in rope due to changing temperature.

Chelan County PUD, Rocky Reach Dam

A. The Rocky Reach SBCS is effective for bypassing juvenile fish. A few complications have developed after start-up. A Hypalon fabric that was used to provide a transition into the entrance slot, failed and was removed after two weeks operation. The cause of failure has not been determined. The Hypalon skin failure was likely associated with placing the lower strength fabric over a rigid frame. The fabric had no mechanism for load relief (which a flexible support mechanism would offer). Consequently, when exposed to wind and/or water generated dynamic loads, the fabric failed.

B. The accumulation of surface trash at Rocky Reach is finding its way into the surface collector. The original design did not allow for cleaning by a trash brush. During fabrication, a brush system was added. The action of the brush is typical to what is normally used for trashracks. The horizontal brush is lowered by gravity and raised by a wire rope winch. The trolley is manually relocated and the process is repeated. When the trolley is relocated, the brush must be coached by hand over the structural cross members. At the time of the visit, one of the two brushes was off-line due to a failure of the wire rope attachment lug to the brush assembly. A debris skimmer was being developed for the vertical slot intake.

Due to the geometry of the structure, consideration should be given to installing fixed hoists with larger brushes. This would allow for pushbutton or timed cleaning operations.

Grant County PUD, Wanapum Dam

A. The Wanapum Dam dewatering system appears to function well as a SBCS. The system does not have an installed means for backwash or screen cleaning. Current alternatives for screen cleaning are either use a long handled brush or removing and reinstalling the blowers facing toward the screen. Debris problems are reported to be minimized with the slot intake fully submerged. By reversing the blowers, water can be backflushed through the screens. It was reported that changing the direction of flow requires about 30-minutes for each blower bank. Consideration should be given to installing a reversible motor starter to reverse the flow through the blower.

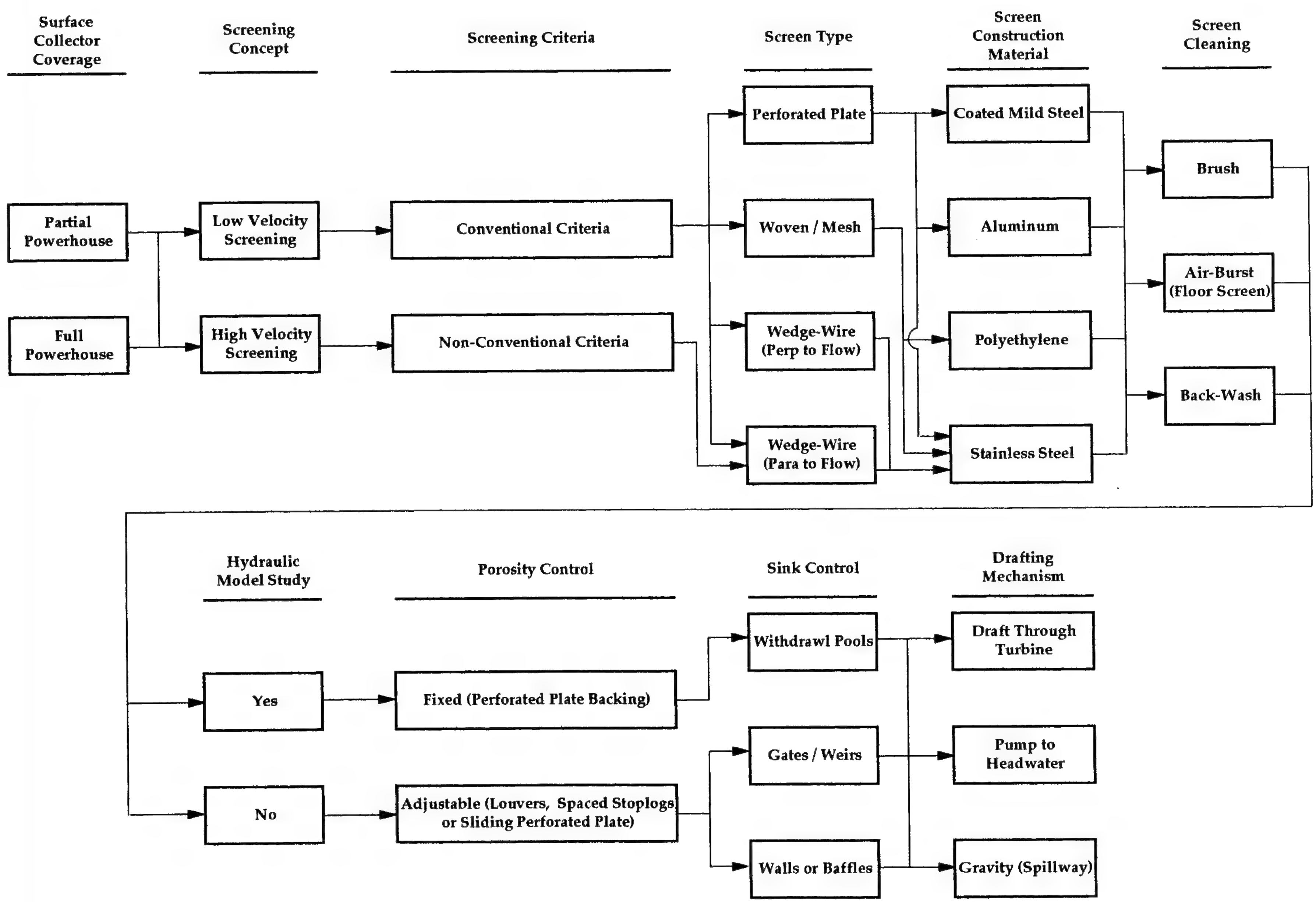
B. It should be noted that the outfall is a fully pressurized system with the flow controlled by a 30% open knife gate. This design was approved by NMFS through a physical modeling effort. The design is similar to the current system at Lower Granite, except the rate of depressurization is instantaneous. At Lower Granite, the rate of depressurizing is in the order of several minutes.

Pacific Power & Light, Wapatox Canal

A. The Wapatox Canal fish diversion system is the most graceful of all sites visited. The hydraulics of the system are balanced and the brush cleaning system operates effectively. The only reported significant operating problem was due to ice and frazil ice accumulation. The ice which collects in front of the trashrack can be moved by a backhoe into the screen emergency bypass system. The Operator suggested that the control for the bypass should be downstream of it's current location and the channel leading up to the gate shaped to eliminate any dead spaces. The penetration of the bypass channel into the main channel could be blocked with stoplogs to prevent fish from entering the bypass channel.

B. The frazil ice problem is more difficult to solve. The brush can remove the frazil ice from the screening surface, but the ice between the bars cannot be removed. Enclosing the structure, providing curtains from the water surface to underside of the flooring, and applying heat to the bars may improve the situation. The most reasonable approach would be to simply bypass the screens during extremely cold periods when frazil ice is present. It should be noted that during the extremely cold periods, fish movement would likely be limited and the chances of entrainment is reduced.

Juvenile Fish Dewatering Options Flow Chart



RESPONSES TO "QUESTIONNAIRE FOR DEWATERED JUVENILE FACILITY"
Rex Baxter, Project Fishery Biologist, Little Goose Dam

Note: Some questions are not answered. Also, some of the answers may be more detailed than you want or need but perhaps some of the "principles" described will be of use.

DEWATERING SYSTEMS

1. Describe any identified problems/deficiencies with this system.

Delay in fish passage is a problem in both the collection channel and primary dewaterer at Little Goose. We need a way to move fish downstream during normal operation and when the facility is dewatered. Maybe a sonic device which "scares" fish downstream would be appropriate. A floating sonic device could be placed in the upstream end of the collection channel and then retrieved downstream at the primary dewaterer. Such a device might move too fast, however. Another option would be to wire the full length of the collection channel and primary dewaterer and have sonic devices activated in series, something like airport runway lights. Operating such a device would require considerable care because, for example, you would not want 5,000 pounds of fish entering a fish separator in a short period of time.

The primary dewaterer at Little Goose is made of steel, rather than concrete. Although the steel is painted, every few years we'll have to paint again.

Debris can overwhelm the primary dewaterer's screen cleaning system. The screen is cleaned by brushes mounted on a chain drive. This works fine 99.9% of the time. However, on one occasion we got a sudden influx of green locust leaves in July which completely covered the screen and forced a shutdown. The leaves were about 2 inches deep. We don't know where the leaves came from. After that, we investigated the possibility of installing an "air-burst fish screen cleaning system" (see enclosed article) and some design work for Little Goose was done by Scott Ross at NPW. The idea here is to "float" debris off the screen using air bubbles. We have not installed an air-burst system at Little Goose, in part because Scott's design does not look adequate to me. The design does not appear to distribute air bubbles over a wide enough area of the screen. I believe an air-burst system in combination with a brush sweep system would be ideal at Little Goose.

The possibility of a zebra mussel infestation must be considered. Although zebra mussels are not yet known to exist in the Snake River drainage, they are likely to show up someday according to at least some experts. These animals are causing considerable damage to power plants in the central United States. The primary dewaterer at Little Goose has a lot of areas where zebra mussels could attach and be difficult to get at for removal (under I-beams for example). The Bureau of Reclamation has done a lot of research on zebra mussels. I presume the Corps' Waterways Experiment Station is also studying zebra mussels. Several years ago I suggested to a Reclamation zebra mussel researcher that perhaps electricity could be used to prevent zebra mussel larvae from attaching to structures. I don't know what became of the suggestion. All design work on surface collectors and dewatering systems MUST consider zebra mussel control.

2. What types of trash are encountered and when?

"Tumbleweeds" arrive mainly after summer wind storms and large masses can accumulate on turbine intake trashracks. There is a surprising amount of plastic in the Snake, including candy wrappers, pop bottles, shotgun wads, and black plastic that perhaps farmers use to cover haystacks. We get a few wood chips, presumably blown off of barges. Other woody debris includes willow stems, driftwood, and sizable logs.

Lower Granite, being further upstream, always gets more debris than Little Goose. Personnel at Lower Granite do a nice job of cleaning the river for those of us further downstream. I would guess that Lower

Monumental gets less debris than Little Goose, although the Tucannon River enters the Snake between these two dams. McNary probably gets more debris than any of the Snake River dams, certainly more aquatic plants. Most trash arrives at Snake River dams with the high flows of April, May, and June.

3. What methods are used for dealing with trash and how effective are these methods?

At Little Goose we try to get a jump on debris before it gets into the juvenile fish system. Debris in the forebay is occasionally removed with a crane and clamshell (not very effective, slow and labor intensive). We have also juggled unit operation to move forebay debris toward the spillway and then opened some spillway gates to pass the debris (very effective, but the problem just goes to the next dam).

We remove debris in the gatewells by using a high pressure air hose and a debris basket raised and lowered by a crane (very effective). The weighted air hose is lowered by hand into one side of the gatewell and floating debris is pushed by bubbles to the opposite side of the gatewell. Then the basket is lowered into the open water and the air hose is moved to the opposite side so that bubbles push debris into the basket.

Orifices are cleaned in four ways. By closing an orifice valve, debris which is impinged on the upstream side simply floats to the water surface in the gatewell where it can be removed as described above. This works fine if the orifice is not largely plugged. When an orifice is largely or entirely plugged, we close an orifice valve and then backflush with air bubbles. Occasionally, a hooked steel rod is inserted into the open orifice from the downstream (collection channel) side and debris is pulled out. On rare occasions, a sizable piece of wood may be stuck in an orifice. In this case, a caisson is lowered into the gatewell and a worker is able to remove the debris by hand. One problem we have at Little Goose is that the orifice discharges are mostly or entirely underwater so we usually cannot see if an orifice is partially blocked. A complete blockage is obvious, judging from the reduced discharge.

4.

5.

6. What operations appear to be the most harmful to the fish and what could minimize the damage?

Completely dewatering the collection channel and primary dewaterer at Little Goose requires hand removal of fish. The fish are scared by dewatering , netting, bucketing, and people splashing around. It would probably be better to scare the fish out of the system with, say, a sonic device prior to dewatering.

7.

8. What equipment has a high exposure to failure and should be provided with some redundancy or back-up?

Electrical systems should be backed up by air pressure systems to the extent possible, and vice versa. See no. 9 below.

9. What features, if failed, will cause a cascade effect and damage fish or other equipment?

A power outage at the primary dewaterer could cause problems, especially if prolonged. The motors for the cleaning brushes would not work. If we had an effective air-burst system that could be turned on by hand, that would get us through any critical period. The motor for the water level control weirs also would not work. The weirs can be moved with an air wrench, however, if necessary. The weirs can also be moved by turning a handwheel, but this is extremely slow and tiring. We have a Milltronics water level sensor that I presume has a battery back-up. I also presume the battery is a good one. Without a battery back-up, the program memory would be lost.

There is actually a long period of time (April to September) when the water level control weirs do not have to move. This occurs when the Little Goose reservoir is operated at minimum operating pool (bottom 1' of the normal 633'-638' operating range). As long as there is little fluctuation in the reservoir, the head differential between the reservoir and orifices is essentially constant. Therefore, discharge through the orifices remains essentially constant and the weirs can remain stationary for months.

Freezing weather might cause ice to form on the water surface in the stilling well (part of the water level control system). The underwater pipe connecting the stilling well to the main channel of the dewaterer is only about 1" in diameter. A larger pipe would increase the turnover of water in the stilling well and would also be less subject to blockage by debris and silt.

Vibration from falling water moves the entire structure of the primary dewaterer. We have not found any cracks yet, though.

10. What hydraulic control equipment (weirs, gates, valves, etc.) work well and which do not?

The cleaning brushes work well most of the time, although the drive chains have come off their sprockets. We finally got the chain tension just right.

The weirs and Milltronics equipment have been very reliable. For details, call Steve Featherston (Electrical Foreman) at Little Goose (509-399-2233).

As a general rule, I would avoid using large <u>air-operated</u> knife valves. As an example, we have a 30" knife valve (not associated with the primary dewaterer) which originally was air-operated. We wanted to open it slowly so that water would pass through. At first the valve would not move because the pressure was building in the air cylinder. Then all of a sudden it opened some 8" as pressure reached a critical point. When working with such an energy transition, it is best to do it slowly. We eventually replaced the air cylinder with an electric motor (Limitorque) which provides better control.

11. What electronic control equipment (level sensors, flowmeters, etc.) work well, require excessive maintenance, have too much sensitivity, or too small of a dead band.

The Milltronics level sensors used on both the adult fish and juvenile fish facilities have been very reliable. For details, call Steve Featherston (Electrical Foreman) at Little Goose (509-399-2233).

<u>GENERAL</u>

12. What methods are currently used to attract and transport juvenile fish around the dam?

Juvenile fish tend to go where most of the water goes, either into the turbine intakes or through the spillway. A few go down the fish ladder or into the navigation lock.

13.

14.

15. Have any site specific studies been done on FGE, fish distribution, passage mortality, etc.?

FGE - Yes, at least two good studies spanning several years.

Fish distribution - Only vertical distribution as found during FGE studies, no horizontal distribution studies as far as I know.

Passage mortality - Some research has been done on spillway, turbine, and bypass system mortality. The juvenile fish facilities have large amounts of data on mortality as a result of daily operations. If you wanted to compare pre-surface collector mortality with post-surface collector mortality, ask me more.

19. What methods are currently being used to dewater the bypass flows and handling of the juvenile fish and resident fish?

We usually dewater the juvenile system about December 1. All orifice flows are turned off. The collection channel and primary dewaterer are slowly drained by opening a valve in the floor of the dewaterer. When the water becomes about 5" deep in the collection channel, two workers enter the channel and walk to the upstream end. From there fish are chased downstream toward the dewaterer with nets (floor slopes downward). Many fish head downstream on their own without being chased. About this time we install two stoplogs at the upstream end of the dewaterer (water depth about 2') in order to pond water there and create a temporary refuge for fish. Fish accumulate in this ponded water and are netted into a tank (about 100 gallons). The tank is lifted out by a crane and a whipline on the crane dumps fish into the adjacent fish ladder (very handy). The tank is refilled by dipping it in the fish ladder and is then positioned to receive more fish.

20.

21.

22. Please provide any other comments or literature references which would help in identifying an effective passage system.

Juvenile fish tend to stack up in the forebay, rather than promptly moving through and past the dam. Squawfish (predators) like this situation. Some means should be developed which would encourage juvenile fish to promptly pass the dam. Maybe sonic devices would work. Maybe a surface collector should include a skimmer which gently crowds fish into the remainder of the collection system. Although a surface collector may have an attraction flow on the order of 2,000 cfs, this attraction flow would pale in comparision to spillway flows.

The design of a surface collector (floating curtain) should consider the effects of wave action, of course, and even vandalism. At Little Goose the wind usually blows upstream, although occasionally it blows downstream (from the east). A stiff wind from the east can cause swells on the order of 2' high in the forebay. We have a rather substantial floating debris boom maybe 100' long in front of the fish ladder exit. The boom has been torn loose from its anchoring at least twice in the past several years by wave action. It would be undesirable to have a huge floating curtain get impinged on a spillway or powerhouse due to wind action or vandals. Firm anchoring for a floating curtain is, of course, a must. I don't know whether the floats should be flexible or rigid. I suggest including sensors which would sound an alarm in the dam's control room should the curtain move out of position. An emergency response plan would also be wise.

Rex Baxter

CENPW-OP-MC 1130-2-400) (Brad Eby) 4 May 1995

MEMORANDUM FOR: CENPW-EN-DB (Steve Fink)

SUBJECT: Response to Scoping Questions On Surface Collection

1. Reference subject document Dated, 2 March 19, 1995, Surface Bypass and Collection System - Scoping Questionnaire.

2. Many of the questions were answered from personal interviews during two site visits by Stone and Webster and District employees at McNary. Included here are outlines on most of those comments and some addition observations, as well as, some data on fish lengths.

#1. Pre-operational evaluations for fish health and conditions revealed virtually no problems in the new system in terms on descaling or fish injury. Mortality the first season was fairly low at 1.48%. Some delay was observed in the collection channel in the area of the dewatering structures and adult fallbacks were also found to be holding in the system at both ends of the channel.

#2. Debris encountered in the system ranges from extremely small, fine periphytonous algae to small sticks and grasses, woodchips, tumble weeds, green pond weeds to larger woody sticks and limbs. The spring time of the season is more typical of tumble weeds and dead leaves and grasses and the late summer/ fall produces more aquatic plant material. Woody material is usually more prevalent early in the season due is highly variable in quantity from year to year.

#3. Floating debris in the forebay is dipped and hauled away early in the season. Trash racks are raked when STS are lowered and as needed through out the season. All material coming through the orifices and into the collection channel are remove from the separator and/or raceways.

#4 & #5. These questions answered through hydraulic design.

#6. Biggest problem for McNary is temperature shock of fish from encountering thermal gradients in the reservoir and while passing through the system. These shocked, incapacitated fish are unable to swim effectively and become impinge on dewatering screens. In summary, Dewatering operations are usually the most harmful to fish. A second stressful point in the system is truck and barge loading operations

#7. Plugging of water diffusion screens by fine debris from the back side (source) was a major problem. Separator and

raceway inflow screens had to be removed and cleaned frequently through out the season.

#8. Screen cleaning mechanisms in the collection channel dewatering structure were the most frequent problem the first year. Powercord supply cable deployment failed often. Water level control equipment and programing was another problem.

#9. Most critical is the cleaning mechanism on the Rectangular dewatering screen. Second is the water level control system.

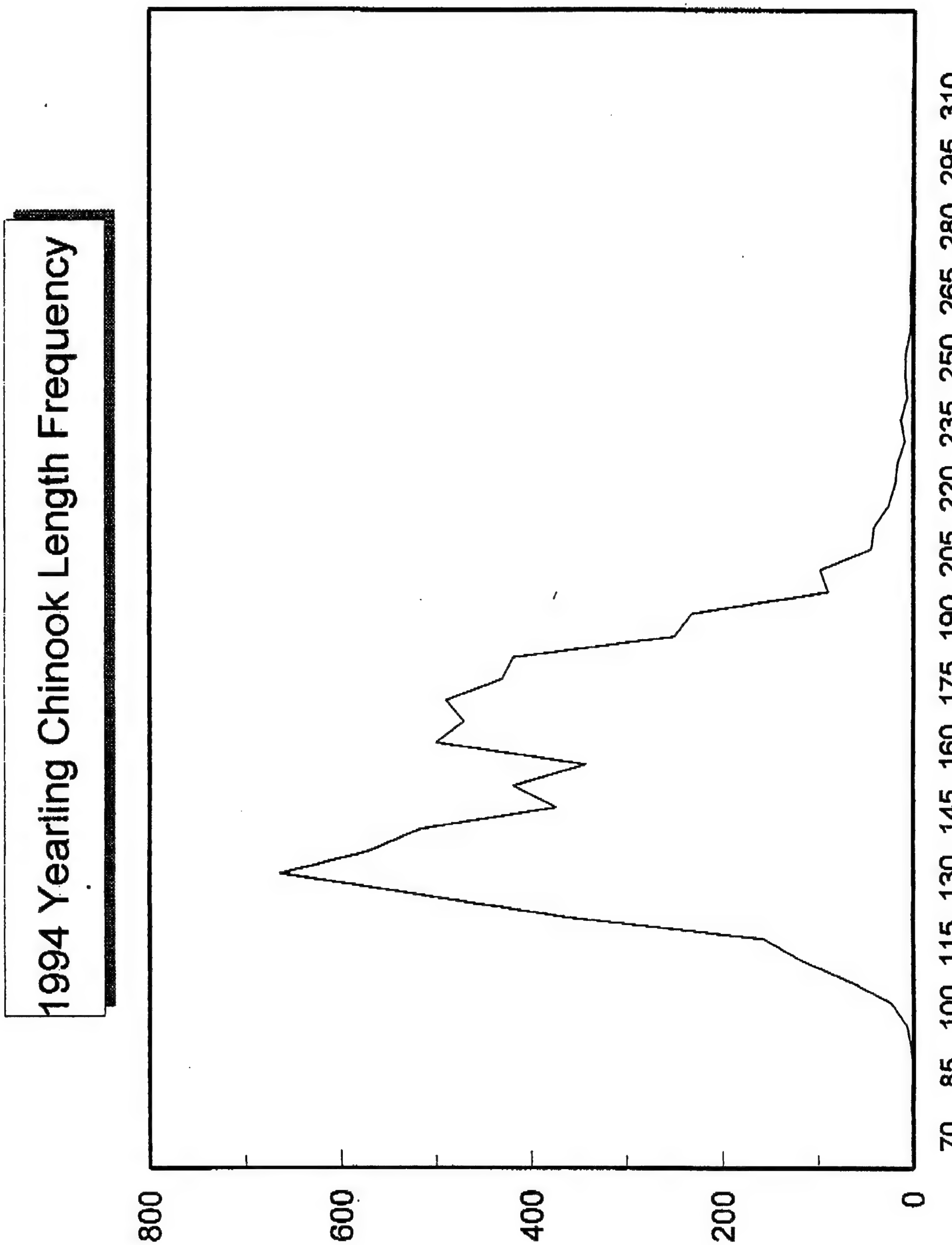
#10. The dewatering sluice gates have not handled the level of vibrations and flow energy they are exposed to and have been very difficult to operate due to alignment shifts and gearbox failure.

#11. We have been able to work with deadband and sensitivity adjustments to maintain fairly good control of the system as long both dewatering valves are working and we do not have too rapid change in generator loads (which effect orifice discharge).

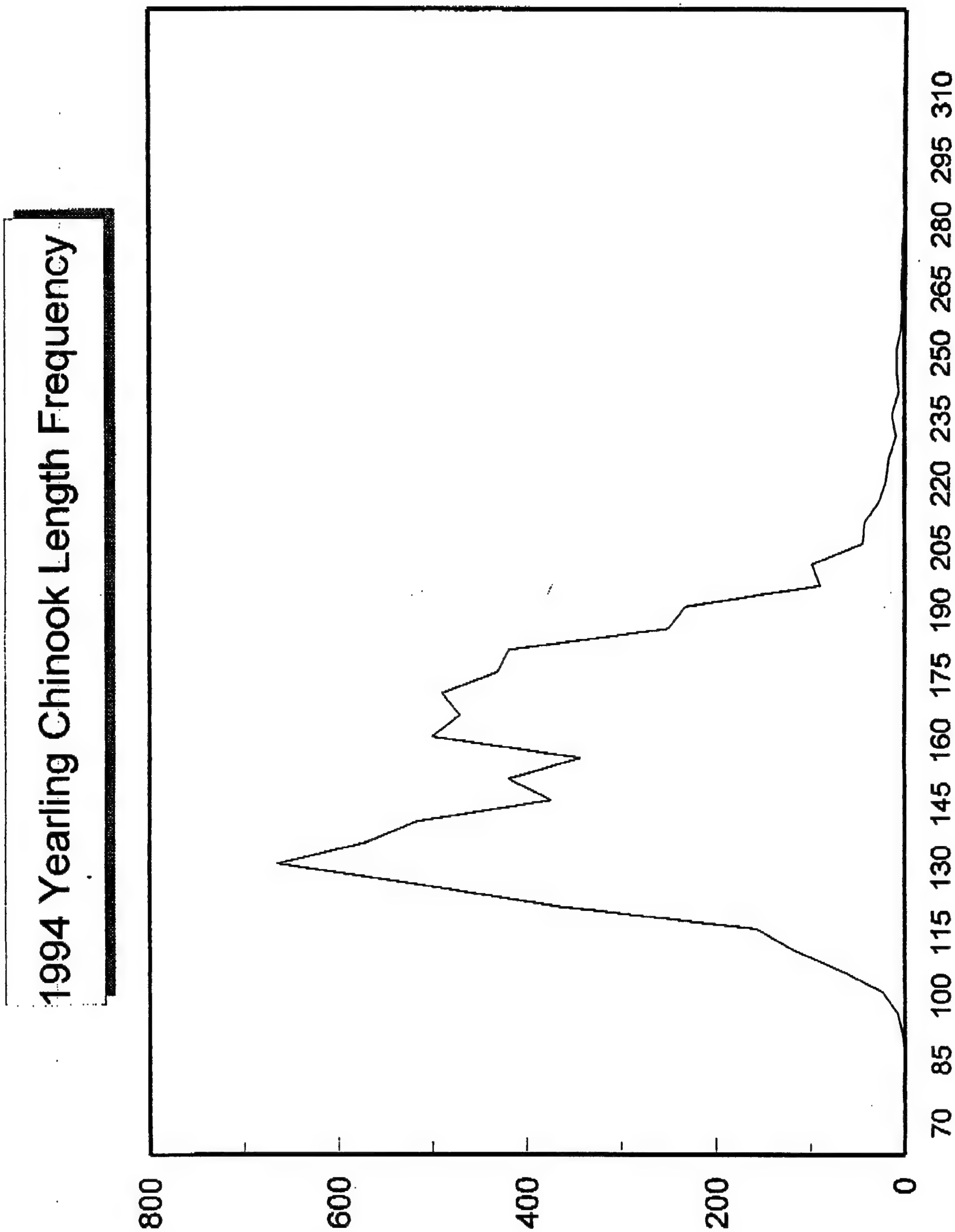
3. Questions listed under the general category (12-22) have been answered by District biologist and engineers, however, we are enclosing a graph of the sizes of fish encountered at McNary for yearling and subyearling chinook and for steelhead. Please feel free to call Brad Eby, extension 242 at any time for further details.

Encl

RICHARD E. BLAKE
Acting Project Manager, McNary


1994 Yearling Chinook Length Frequency
800
600
400
200
0
70
85
100
115
130
145
160
175
190
205
220
235
250
265
280
295
310

Encl


1994 Yearling Chinook Length Frequency
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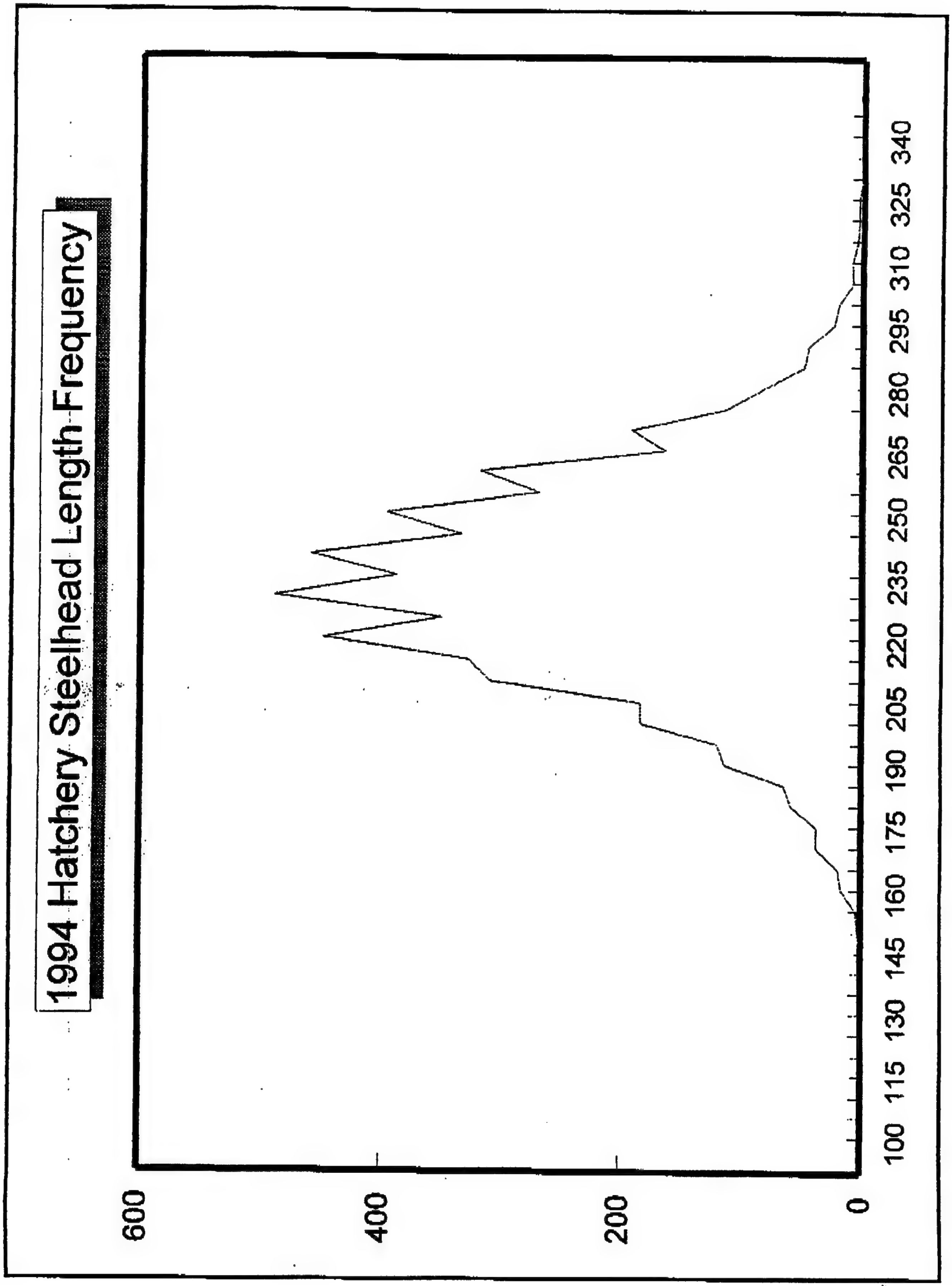
1994 Hatchery Steelhead Length Frequency
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400
200
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100
115
130
145
160
175
190
205
220
235
250
265
280
295
310
325
340

MEMORANDUM

Chuck Palmer - Mechanical Engineer

SUBJECT: Questionnaire for Dewatered Juvenile Facility — Wed, Mar 1, 1995

March 6 to 10, 1995

U.S. Army Corps of Engineers, Walla Walla District (NPW)

The Walla Walla District (NPW) and Stone & Webster Engineer Corp. (SWEC) have teamed to develop a dewatering system for the Lower Granite Juvenile Bypass and Collection System. To take advantage of project experience at the Lower Snake River and the Columbia River, a team of Biologists and Engineers will be visiting McNary, Lower Monumental, Little Goose, and Lower Granite. The primary focus will be on the existing dewatering systems, and assessing each systems design and performance. To facilitate the collection of operating experience the following questionnaire was developed to identify general areas of interest for the Site Visits and to have appropriate project personnel available to address these questions. Each Project and the District is requested to respond to these questions by March 20, 1995 and provide those responses to Steve Fink (NPW).

The first eleven questions specifically focus on the dewatering systems; the later are more general in nature. It is hoped that the responses will not provide direct answers, but rather add insight as to what works well and items that can be improved. Suggestions which may lead to more effective solutions will be appreciated.

DEWATERING SYSTEMS

1. Describe any identified problems/deficiencies with this system (e.g., descaling, mortality, behavioral avoidance or delay in passage, etc.). Screen plugging seems to be the worst problem. I'm a big proponent of a water back-flush for cleaning the dewatering screens. For instance, design the system with 3 sections of dewatering - two of which alone to handle dewatering flows while the 3rd is in back-flush mode. Alternate Back-flush between the 3 sections.

2. What types of trash are encountered and when ?

3. What methods are used for dealing with trash and how effective are these methods ?

MEMORANDUM

4. What is the bar spacing for the dewatering system ?

(I wouldn't discount a reinforced perf. plate system. I believe they are easier to keep clean.

5. What are the velocities perpendicular and parallel to the screening surfaces ?

6. What operations appear to be the most harmful to the fish and what could minimize the damage ?

7. What maintenance items appear to be excessive and should be explored to minimize the effort to maintain the equipment ?

8. What equipment has a high exposure to failure and should be provided with some redundancy or back-up ?

9. What features, if failed, will cause a cascade effect and damage fish or other equipment?

Plugging of the dewatering screen probably most critical.

MEMORANDUM

10. What hydraulic control equipment (weirs, gates, valves, etc.) work well and which do not.

We've had nothing but problems with sluicegates at McNary which were used for control. Thrust nuts stripped, operating gear boxes destroyed. I think I'd try to stick to butterfly's or V-Ported knife gates for control.

11. What electronic control equipment (level sensors, flowmeters, etc.) work well, require excessive maintenance, have to much sensitivity, or to small of a dead band.

GENERAL

12. What methods are currently being used to attract and transport juvenile fish around the dam ?

13. What are the best and worst attributes of this system ?

14. What methods have been used in the past and how effective were they ?

15. Have any site specific studies been done on FGE, fish distribution, passage mortality, etc.?

MEMORANDUM

16. What is the method for determining the FGE at USACE projects ?

17. Describe by species the size of outmigrants (range, median and frequency) and the distribution in the water column, both vertical and horizontal.

18. Describe the timing of outmigration for each species (onset, peak and end) and to what extent is downstream movement pulsed.

19. What methods are currently being used to dewater the bypass flows and handling of the juvenile fish and resident fish ?

20. Are there any suggestions to simplify the existing designs resulting in increased system reliability ?

21. Are there any construction restraints for future modifications ?

22. Please provide any other comments or literature references which would help in identifying an effective passage system ?

MEMORANDUM

SUBJECT: Questionnaire for Dewatered Juvenile Facility — Wed, Mar 1, 1995
March 6 to 10, 1995
U.S. Army Corps of Engineers, Walla Walla District (NPW)

The Walla Walla District (NPW) and Stone & Webster Engineer Corp. (SWEC) have teamed to develop a dewatering system for the Lower Granite Juvenile Bypass and Collection System. To take advantage of project experience at the Lower Snake River and the Columbia River, a team of Biologists and Engineers will be visiting McNary, Lower Monumental, Little Goose, and Lower Granite. The primary focus will be on the existing dewatering systems, and assessing each systems design and performance. To facilitate the collection of operating experience the following questionnaire was developed to identify general areas of interest for the Site Visits and to have appropriate project personnel available to address these questions. Each Project and the District is requested to respond to these questions by March 20, 1995 and provide those responses to Steve Fink (NPW).

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DEWATERING SYSTEMS

1. Describe any identified problems/deficiencies with this system (e.g., descaling, mortality, behavioral avoidance or delay in passage, etc.). Fish hold in the Dewatering structure + transport channel, I doubt if this is a problem.

2. What types of trash are encountered and when ? straw and woody debris in Spring especially when the Palouse has a good snow pack and melts quickly. In summer some grasses and filametons algae (little problem). In Fall some diciduous leaf litter and twigs (minimal problem).

3. What methods are used for dealing with trash and how effective are these methods ? Woody debris removed from forebay/gate slots/separator by dipping or hand removal (minimal problem). Straw (potential bummer) in 1993 (march) plugged inclined screen of Pri. Dewaterer, We changed the brush to 50 thousands stiff nylon bristles but limited straw load in water column has not tested this fix. Grasses (inconvenient but at levels typically seen can be cut with sharp plexiglass scrapper. Algae (no problem) easily cut from screens with scraper.

MEMORANDUM

4. What is the bar spacing for the dewatering system ?

2 mm

5. What are the velocities perpendicular and parallel to the screening surfaces ?

? I'm afraid this escapes my memory... was it 4-5 feet/sec or .4-.5 feet/sec? Ask Dan Katz in the District Office.

6. What operations appear to be the most harmful to the fish and what could minimize the damage ?

We have had no such problems at Lomo. On second thought dewatering the primary dewaterer requires neting adult + juvenile fish and carring out of dewaterer in a garbage can.

7. What maintenance items appear to be excessive and should be explored to minimize the effort to maintain the equipment ?

Electric valve operator indicators frequently malfunction.

8. What equipment has a high exposure to failure and should be provided with some redundancy or back-up ?

Facility electrical supply.

9. What features, if failed, will cause a cascade effect and damage fish or other equipment?

Facility electrical supply.
Orifice air supply.
Facility air supply.
Raw Water supply.

MEMORANDUM

10. What hydraulic control equipment (weirs, gates, valves, etc.) work well and which do not.

pneumatic orifice slide gates stick (maybe need more air pressure).
Electric butterfly valves stick (probably from infrequent use).
Many of our pneumatic valve operators are not operating correctly we are changing to a vent at the valve on the discharge side.

11. What electronic control equipment (level sensors, flowmeters, etc.) work well, require excessive maintenance, have to much sensitivity, or to small of a dead band.

Flow meters in Raceway supply are not used due to.... ?? maybe algae stopping it from turning?

GENERAL

12. What methods are currently being used to attract and transport juvenile fish around the dam ?

Adults - Stock tanks with lids ~~or~~ very large plastic containers with O_2 supply.

13. What are the best and worst attributes of this system ?

Works fine.

14. What methods have been used in the past and how effective were they ?

This is all we've used since I've been here.

15. Have any site specific studies been done on FGE, fish distribution, passage mortality, etc.?

yes Gessle FGE 1992 also fish distrib same time.
Juven. passage mortality at facility 1993 + 1994 transport report. Other work (pre 1992) unknown

MEMORANDUM

16. What is the method for determining the FGE at USACE projects ?

see Planning

17. Describe by species the size of outmigrants (range, median and frequency) and the distribution in the water column, both vertical and horizontal.

See Gessle 1992 and/or Washington Dept. of Fish + Wildlife Paul Wagner (509) 783-7576.

18. Describe the timing of outmigration for each species (onset, peak and end) and to what extent is downstream movement pulsed.

see transport Report 1993 + 1994 available via Walla[2] Dist. office Dave Hurson.

19. What methods are currently being used to dewater the bypass flows and handling of the juvenile fish and resident fish ? Dewater through wedgewire screens, handle fish with crowders when possible, nets when crowders are impractical. Sample fish are anesthesized with MS 222 and benzocaine and alcohol before handling.

20. Are there any suggestions to simplify the existing designs resulting in increased system reliability ?

No

21. Are there any construction restraints for future modifications ?

yes the facility is crowded into to small an area.

22. Please provide any other comments or literature references which would help in identifying an effective passage system ?

See Lower Monumental prints; this is an effective passage system.

U.S. Army Corps of Engineers
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search Summary

List of All Documents Reviewed by Document Number

Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
1	Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application	EPRI/SWEC	1986	RKG	**Document summarized in Summary No. 1.**
2	Research Update on Fish Protection Technologies for Water Intakes	EPRI/SWEC	1994a	RKG	**Document summarized in Summary No. 2.**
3	Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application	EPRI/SWEC	1994b	RKG	**Document summarized in Summary No. 3.**
4	Biological Evaluation of a Modular Inclined Screen for Protecting Fish at Water Intakes	EPRI/SWEC	1994c	RKG	**Document summarized in Summary No. 4.**
5	Development of a Fixed Horizontal Screen to Prevent Transbasin Fish Transfer	Johnson, Perry L. and Stephen J. Grabowski	1980	SRT	Fish screen sloping down in the downstream direction reduced debris deposition on screen. 70-mesh phosphor bronze screen prevents passage of fish, eggs and larvae. Water jet cleaning system worked well except for algae.
6	Current TVA Work on the Fluid Mechanics of Screens with Very Small Openings for the Exclusion of Larvae at Power Plant Cooling-Water Intakes	Vigander, Svein	Unknown	SRT	Larvae exclusion not relevant.
7	The Johnson Screen for Cooling Water Intakes	Cook, Lee E.	Unknown	SRT	Examines velocity distributions around pipe screens.
8	Biological Engineering Investigation of Angled Flush Fish Diversion Screens	Taft, E.P. III, and Y.G. Mussalli/SWEC	1977	RKG	Discusses the use of angled fish screens for fish protection at cooling water intakes. Screens were angled at 25° to the direction of flow with 1.0 fps approach velocity.

List of All Documents Reviewed by Document Number

Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
9	Cleaning and Clogging Tests of Passive Screens in the Sacramento River, California	Smith, Lawrence W. and David A. Ferguson	1978 (est.)	RKG	Detailed analysis of debris types and loads based on time of year for the Sacramento River in California. Comparing screens of similar fish screening efficiency, perforated plate clogged faster then wire mesh which clogged faster than wedge-wire. Preliminary data from cleaning tests indicate all screens can be easily cleaned with water jet spray or a wiper brush.
10	Headloss Characteristics of Six Profile-Wire Screen Panels	Stefan, Heinz and Alec Fu	1978	RKG	Headloss coefficients for various screens at various orientations.
11	Air-Burst Fish Screen Cleaning System for the Twin Falls Hydroelectric Project	Ott, Ronald F. and Donald P. Jarrett	1991	RKG	**Document summarized in Summary No. 5.**
12	Water Intake Structures Design for Fish Protection	ASCE Committee on Hydraulic Structures	1981	RKG	Not relevant. Fish protection for cooling water intakes are based on four concepts; Fish collection and removal, Fish diversion, Fish deterrence and Physical exclusion. Focus of paper is on bucket type traveling screens which impinge fish and back wash them into a collection channel. Minor discussion on angled screens.
13	Fish Protection at Hydro Plants: Assessment of New and Old Technologies	Taft, E.P./SWEC	1986	RKG	General discussion on Behavioral barriers, Physical barriers, Collection systems and Diversion systems.
14	Studies of Fish Protection Methods at Hydroelectric Plants	Taft, E.P., J.K. Downing, and C.W. Sullivan/SWEC	1987a	RKG	Summary paper regarding selection of sites (Hadley Falls/Holyoke, Ludington Pumped Storage Facility, Wapatox Canal and Wanapum) for "Behavioral" testing of mercury lights, spill, sound and limited screening.
15	Effective Control Technologies for Zebra Mussels: Worldwide Experiences	Mussalli, Y.G./SWEC	1990a	RKG	Not Pertinent. Covers chemical and non-chemical control methods for Zebra Mussels.
16	Recent Progress in Zebra Mussel Research	Mussalli, Y.G. and J.S. Mattice/SWEC	1990b	RKG	Not Relevant. Discusses EPRI's Research and Development Plan and Guidelines for Zebra Mussel control.

List of All Documents Reviewed by Document Number

Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
17	New Infiltration Intake System for Zebra Mussel Control and Larval Exclusion	Mussalli, Y.G., M.M. Elarbash, and R. Cheesman/SWEC	1991	RKG	Not Relevant. General paper which discusses a filtration intake system. No detailed discussion.
18	Grass Control at Water Intake Structures	Mussalli, Y.G./SWEC	1990c	RKG	Not Relevant. General discussion of screen blockage caused by grasses at cooling water intakes.
19	Evaluation of an Eicher Fish Diversion Screen at Elwha Dam	Winchell, F.C. and C.W. Sullivan/SWEC	1993a	RKG	The concept of installing a fish screen inside of a penstock at a shallow angle to the flow was first applied by George Eicher at the T.W. Sullivan hydro plant in Oregon. This type of screen is now commonly referred to as an "Eicher Screen". Its basic principle is to sweep fish rapidly towards a bypass at high velocities, as opposed to other types of screens which are designed to maintain velocities lower than the swimming speed of the target fish species.
20	DRAFT REPORT: Surface Flow Attraction Alternative - Wanapum Development, Juvenile Fish Bypass System, Priest Rapids Project	Sverdrup Corporation	1993	RKG	**Document summarized in Summary No. 6.**
21	Wanapum Attraction Flow Prototype - Bid Drawings and Specifications	Sverdrup Corporation	1994a	RVD	**Document summarized in Summary No. 7.** (INCOMPLETE)
21A	Wanapum Attraction Flow Prototype Brochure	Sverdrup Corporation	1994b	SRT	Summary of prototype design features with color isometric views of the facility and color photos during construction.
22	Hydraulics of a New Modular Fish Diversion Screen	Cook, T.C., E.P. Taft, G.E. Hecker, and C.W. Sullivan/SWEC	1993	RKG	**Document summarized in Summary No. 8.**
23	Biological Evaluation of a Modular Fish Screen	Winchell, Fred, Steve Amaral, Ned Taft, and Charles Sullivan/SWEC	1993b	RKG	**Document summarized in Summary No. 9.**

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
24	Review of Fish Entrainment and Mortality Studies	Taft, Ned, Fred Winchell, John Downing, Jack Mattice, and Charles Sullivan/SWEC	1993	RKG	Average salmonoid mortality rate for Kaplan turbines is 7.6% and for Francis turbines is 18.2%.
25	Research Update on the Eicher Screen at Elwha Dam	Winchell, Fred, Ned Taft, Tom Cook, and Charles Sullivan/SWEC	1993c	RKG	**Document summarized in Summary No. 10.**
26	Net and Hydroacoustic Monitoring of Fish Passage	Downing, John, Paul Martin, Ned Taft, and Charles Sullivan/SWEC	1991	RKG	Not relevant. Hydroacoustic systems generally over-count the numbers of fish passed relative to the number of fish collected downstream in the collection net.
27	A Demonstration of Strobe Lights to Repel Fish	Martin, Paul, John Downing, Ned Taft, and Charles Sullivan/SWEC	1991	RKG	Not relevant. Deals with repelling American shad from intakes with strobe lights.
28	Evaluation of an Eicher Fish Screen at Elwha Dam	Winchell, Fred C. and Charles W. Sullivan/SWEC	1991	RKG	Older version of Doc. No. 25 which gives some background to the development of the Eicher Screen.
29	Successful Behavioral Devices for Fish Protection	Taft, E.P./SWEC	1989	RKG	Not relevant. Results indicate that the response of fishes to mercury lights, strobe lights and sound devices are species- and device-dependent. Sound devices have not resulted in any significant fish response. Strobe lights either repel fish or have no effect. Mercury lights attract some species, repel others and have no discernible effect on still others.
30	Influence of Three Sonic Devices on Fish Behavior	McKinley, R.S., P.H. Patrick, and Yusuf Mussalli/SWEC	1987	RKG	Not relevant. Pertains only to using sound to repel/attract fish.
31	Studies of Fish Protection Methods at Hydroelectric Plants	Taft, E.P., J.K. Downing, and C.W. Sullivan/SWEC	1987b	RKG	Not relevant. Pertains only to using mercury lights to attract fish.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
32	Preventing Fish Mortality at a Large Pumped Storage Plant	Taft, Edward P., B.N. Mochrie, T. Wright, and M. Bronoski/SWEC	1985	RKG	Describes five schemes for protecting fish from passing through the turbine when operating in the pumping mode. The schemes selected were: angled bar screens, angled fish louvers, bar racks in the existing trash rack slots, bar racks on the face of the powerhouse and bar racks across the tailrace.
33	Preventing Fish Mortality at Hydropower Facilities	Taft, Edward P. III, Elaine Bazarian, and Thomas C. Cook/SWEC	1983a	RKG	General paper summarizing the three categories of fish protection devices: behavioral barriers, fish collection systems and diversion/deterrent devices.
34	State-of-the-Art in Preventing Turbine Mortality at Hydro Facilities	Taft, Edward P. III and Elaine Bazarian/SWEC	1983b	RKG	Parent document of EPRI's 1986, "Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application", EPRI AP-4711.
35	Study of Fish Protection Methods Related to a Potential Alaskan Hydropower Development	Taft, Edward P. III and John S. Isakson/SWEC	1983c	RKG	This paper discusses placing traveling screens in a Vee type configuration in a turbine intake for a proposed hydroelectric facility. Testing presented in the paper deals mainly with fish impingement on the screen and not detailing screening methods.
36	Design of Fishways and Other Fish Facilities	Clay, Charles H.	1995	RVD	**Document summarized in Summary No. 11.**
37	High Performance Traveling Water Screen for Millstone - Unit 3 Water Intake	Mussalli, Y.G., M. McNamara, and R. Cheesman/SWEC	1993a	RKG	Traveling water screen supplied with fiberglass buckets for seaweed control at 350 cfs service water intake.
38	High Performance Traveling Water Screen for Millstone - Unit 3 Water Intake	Mussalli, Y.G., M. McNamara, and D. Gass/SWEC	1993b	RKG	Re-write of as Doc. No. 37, same information.
39	Development of High Performance Traveling Water Screen for Millstone - Unit 3 Water Intake	Mussalli, Y.G., M. McNamara, and R. Cheesman/SWEC	1993c	RKG	Re-write of as Doc. No. 37, same information.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
40	Controlling Fish Movement with Sonic Devices	Mussalli, Y.G., R.S. McKinley, and P.H. Patrick/SWEC	1988a	RKG	Not relevant. Tests using a fishdrone (sonic vibrations), speaker system and hammer (spring mass impact device) indicated that the use of acoustic stimuli either to attract or repel fish is generally ineffective.
41	Design of Operation of Angled-Screen Intake	Mussalli, Y.G., J.A. Divito, and M.R. Anderson/SWEC	1988b	RKG	Cooling water intake provides two means to bypass fish. Fish diverted along the traveling screens are diverted into a bypass slot and pumped into the river. Fish impinged on the traveling screens are washed off the backside by a low pressure spray into a fish trough and returned to the river.
42	Hydraulic Aspects of a Low-Velocity, Inclined Fish Screen	Locher, F.A., V.C. Bird and A.J. Odgaard	1993a	RKG	Not enough information in the document to get a good understanding for designs. Some concepts should be looked into further. More research required. Wedge-wire screens (Hendricks B9) with 1/8" openings; screens are oriented perpendicular to the flow.
43	Fish Screen Developments Columbia River Dams	Weitkamp, D.E. and R.A. Elder	1993	RKG	Wedge-wire bar screens were determined to be preferable at Wanapum and Priest Rapids rather than the mesh used on traveling screens (in the gatewell). Vertical barrier screens in the gatewells are perforated plate with 3/16" holes (51% porosity). A second layer of perforated plate was installed on the downstream side to equalize the flow distribution.
44	Hydraulic Modelling of Fish Screens	Odgaard, A.J., Y. Wang, M. Serre and R.A. Elder	1993	RKG	The effort underway at Iowa Institute of Hydraulic Resistance (University of Iowa) is an attempt to create a data bank of pressure-loss coefficients for typical screen configurations.
45	Long Term Hydroacoustic Evaluations of a Fixed In-Turbine Fish Diversion Screen at Rocky Reach Dam on the Columbia River, Washington	Steig, T.W. and B.H. Ransom	1993	RKG	Not relevant.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
46	Grizzly Powerhouse's Environmental Intake	Rothfuss, B.D. and W. E. Zemke	1993	RKG	Fish screen by Bixby-Zimmer (BeeZee), SS bars taper from 3/16" wide (upstream) to 1/8" wide (downstream). The 5 degree taper prevents debris from binding between bars. Trashrack is a 60-foot long double boom with a teflon scraper.
47	Debris Removal From a Low-Velocity Inclined Fish Screen	Locher, F.A., P.J. Ryan, V.C. Bird and P. Steiner	1993b	RKG	**Document summarized in Summary No. 12.**
48	An Improved Fish Sampler At Cabot Station	Whitfield, J.R., G.E. Hecker and T.D. Nguyen	1993	RKG	Not relevant. Bypass of small flows through inclined wedge-wire screens.
49	Development of an Eicher Screen at the Elwha Dam Hydroelectric Project	Adam, P., S.P. Jarrett, A.C. Solonsky and L. Swenson	1991	RKG	Eicher screens are penstock applications. Basic screen concepts may be helpful in dewatering system design. Wedge-wire screen manufactured by Hendrick Screen Co., porosity varied from 8% upstream to 63% downstream, which results in fairly uniform normal velocity component for the entire length of screen.
50	Design of Extended Length Submerged Traveling Screen and Submerged Bar Screen Fish Guidance Equipment	Bardy, D., M. Lindstrom and D. Fechner	1991	RKG	Debris is cleaned from the submerged bar screens by brushes attached to roller chains. Cleaning is done every 15 minutes. Document gives overview of the Extended Submerged Bar Screens (ESBS) and difficulties of design and implementation.
51	Turbine Intake Modification for Fish Passage	Ismail, F., R. Vaughn and R. Walker	1987	RKG	Not relevant. This paper concentrates on modifying the turbine intake to draw near-surface juveniles down into the turbine intake.
52	Innovative Intake Protects Both Aquatic Life and Turbine Equipment	Ott, R.F., E. Boersma and J.J. Strong	1987a	RKG	Dewatering system used concave screens (Coanda-type). Application has been for small hydro projects (<3 MW) and small flows (<120 cfs).
53	Research to Improve Bonneville Second Powerhouse for Migrating Juvenile Salmon	Mih, W.C.	1987	RKG	Not relevant. Same as Document No. 51, modified turbine intake to draw near-surface juveniles down into the turbine intake.
54	Arbuckle Mountain Hydro Vertical-Axis Fish Screens	Ott, R.F., J.J. Strong and H.E. Finch	1987b	RKG	Cylindrical-type wedge-wire screens used for small flows.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
55	Protection of Juvenile Anadromous Fish	Haider, T.R. and P.H. Nelson	1987	RKG	Focus is on drum screens.
56	Development of Turbine Intake Downstream Migrant Diversion Screen	Elder, R.A., A.J. Odgaard, W. Weitkamp and D. Zeigler	1987	RKG	Details development of submerged bar screens.
57	Fish Screens for Hydropower Developments	Dorratcague, D.E., G.R. Leidy and R.F. Ott	1985	RKG	This document presents older screening technologies (inclined plane, vertical perforated plate, Coanda, circular, and submersible traveling screens) in general terms.
58	Effects of Hydropower Development on Columbia River Salmonids	Rondorf, D.W., G.A. Gray and W.R. Nelson	1983	RKG	This paper deals with the biological concerns of fishery management on the Columbia River system.
59	Revised Juvenile Fish Screening Criteria	National Marine Fisheries Service	1995a	SRT	**Document summarized in Summary No. 13.**
60	Clogging, Cleaning, and Corrosion Study of Possible Fish Screens for the Proposed Peripheral Canal	Smith, Lawrence W. (California Department of Water Resources)	1982	RKG	**Document summarized in Summary No. 16.**
61	Rocky Reach Fish Guidance 1995 Prototype - Construction Drawings	CH2M Hill	1994	SRT	Facility toured and inspected on morning of May 1, 1995.
62	The Dalles Lock and Dam 1995 Prototype Testing - Initial Release Construction Drawings and Specifications	USACE - North Pacific Division, Portland District, Hydroelectric Design Center	1994	RVD	The Dalles prototype involved modificaiton of existing VBS. 1) New steel lined orifices with light tubes were added; 2) The bottom of the VBS was raised and blocked off; 3) The lifting beam was modified; 4) Turning vanes at the base of the VBS were installed; and 5) Spare VBS panels were installed.
63	Rocky Reach Dam Juvenile Fish Bypass - Technical Forebay Hydraulic Data	ENSR Consulting and Engineering	1994a	RVD	ENSR constructed a model of the Rocky Reach forebay to determine the existing vectors and their velocities at various flows. The prototype juvenile bypass was installed and tested with the structure in place.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
63A	Briefing Document for June 7, 1994 Workshop at ENSR Consulting and Engineering on Flow Attraction Alternatives for Juvenile Fish Bypass at Rocky Reach Dam	ENSR Consulting and Engineering	May 1994b	SRT	Summary of field and model observations of forebay hydraulics and fish movement, site specific theory of fish behavior, and results of various flow attraction alternatives leading to the present leading design alternative.
64	Experimental Fish Guidance Devices	National Marine Fisheries Service	1995b	RKG	NMFS believes that positive-exclusion barrier screens are appropriate for utilization in the protection of downstream migrant salmon at all intakes.
65	Environmental Mitigation at Hydroelectric Projects: Volume II - Benefits and Costs of Fish Passage and Protection	Francfort, J.E., G.F. Cada, D.D. Dauble, R.T. Hunt, D.W. Jones, B.N. Rinehart, G.L.Sommers, R.J. Costello	1994a	RKG	See Document No. 65-SUM
65-SUM	Protecting Fish (Summary of Document No. 65)	Francfort, J.E. and B.N. Rinehart	1994b	RKG	Summary of Document No. 65. This report documents the mitigation measures in detail, including performance, monitoring practices, benefits and costs at 16 case study projects. Costs were the major concern not the technology of the fish bypass facilities.
65-11	Leaburg Case Study (Section 11 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994c	RKG	Detailed mitigation cost analysis for the Leaburg Project for use in Document No. 65.
65-12	Little Falls Case Study (Section 12 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994d	RKG	Detailed mitigation cost analysis for the Little Falls Project for use in Document No. 65.
65-14	Lower Monumental Case Study (Section 14 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994e	RKG	Detailed mitigation cost analysis for the Lower Monumental Project for use in Document No. 65.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
65-17	Twin Falls Case Study (Section 17 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994f	RKG	Detailed mitigation cost analysis for the Twin Falls Project for use in Document No. 65.
65-19	Wells Case Study (Section 19 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994g	RKG	Detailed mitigation cost analysis for the Wells Project for use in Document No. 65.
65-20	West Enfield Case Study (Section 20 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994h	RKG	Detailed mitigation cost analysis for the West Enfield Project for use in Document No. 65.
65-23	Summary Table for Downstream Fish Passage/Protection Mitigation (Section 23 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994i	RKG	Table of Downstream fish passage/protection mitigation benefits, levelized annual costs over 20 years (1993 dollars) for use in Document No. 65.
66	Design and Operation of an Angled Screen Intake Structure with Protective Features for Fish and Facilities for Fish Monitoring	Anderson, M.R., J.A. Divito and Y.G. Mussalli/SWEC	1984	RKG	Detailed discussion on power plant cooling water intake fish protection for the Brayton Point Generating Station. Traveling angled screens are used to guide fish to a bypass. Some fish are impinged on the traveling screens and washed off the backside into a fish trough.
67	Using Conventional Fish Screens at Hydroelectric Projects	Solonsky, Allan	1995	RKG	Fashioned in a Question and Answer type format, this article gives general answers to typical questions pertaining to fish screens.
68	Tools for Maximizing Hydropower Generation while Minimizing Water Use	Liddell, Vincent J.	1995	RKG	Not Relevant. Discussion on using existing plant efficiency and flow data as a basis for optimizing water consumption and power output of the facility.
69	Fish Passage and Hydropower Development at the Dalles Dam	DeHeer, Lee	1993	RKG	This paper details the retrofit of The Dalles Dam North Shore Fishway with an Attraction Water Supply System. The system consists of an underground powerhouse with a single 5 MW Francis unit which discharges 800 cfs directly into the fish ladder to provide fish attraction flow.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
70	Use of Flexible Curtains to Control Reservoir Release Temperatures - Physical Model and Field Prototype Observations	Johnson, Perry, Tracy Vermeyen, and Greg O'Haver	1993	RKG	The Bureau of Reclamation is developing flexible curtain barriers to control reservoir release water temperatures for structures in the Trinity River and Sacramento River drainages of Northern California.
71	Two Promising Technologies for Fish Protection at Hydroelectric Projects	Solonsky, Allan C.	1993	RKG	General biological discussion on benefits of high-velocity screening and surface collection.
72	Debris Removal from a Low-Velocity, Inclined Fish Screen	Locher, F.A., P.J. Ryan, V.C. Bird, and P. Steiner	1993c	RKG	Re-write of Doc. No. 47, same information presented.
73	Evaluation of a Louver Array/Bypass System in Bypassing Atlantic Salmon Smolts from the Holyoke Canal to the Connecticut River	Boltz, Jeffrey M., David A. Robinson, Robert J. Stira, and Paul Ruggles	1993	RKG	Evaluation of louver arrays to guide atlantic salmon smolts from the Holyoke Canal. Studies indicate that louvers are an effective means of diverting up to 80% of the smolts.
74	Zebra Mussels in North America: Impact on Hydroelectric Projects	Shephard, Burt K. and Gary M. Hoornaert	1993	RKG	Deals with the control of Zebra Mussels at hydroelectric projects.
75	Examining the Benefits and Costs of Fish Passage and Protection Measures	Cada, Glenn F. and James E. Francfort	1995	RKG	Using 16 U.S. hydroelectric projects as case studies, researchers have determined that fish passage/protection mitigation measures are generally effective. This paper examines the total cost of mitigation on a mills/Kwh basis.
76	Analyzing Turbine Bypass Systems at Hydro Facilities	Ferguson, John W.	1992	RKG	Discussion of a general history of bypass systems at the Columbia and Snake River projects.
77	Improving Fish Survival through Turbines	Ferguson, John W.	1993	RKG	This paper focus' on the studies involved in determining fish mortality when they pass through turbines. Effects of strike, pressure, cavitation, shear, stress and grinding on fish are described.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
78	Introducing a "Modular" Approach to Fish Screen Installation	Taft, Edward P., Fred C. Winchell, Thomas C. Cook, and Charles W. Sullivan/SWEC	1992	RKG	Discussion of the development of the Modular Inclined Screen (MIS) is presented.
79	Improved Cylindrical Pipe Intakes	Richards, R.T.	1979	RKG	Not relevant. Discussion of the history of development of the cylindrical pipe intake which was normally used for small flows in cooling water intakes.
80	Influence of Fish Protection Considerations on the Design of Cooling Water Intakes	Mussalli, Yusuf G., Peter Hofmann, and Edward P. Taft/SWEC	1978	RKG	Not relevant. Deals with fish collection and removal, fish diversion and fish deterrence for cooling water intakes.
81	A Study on the Protection of Fish Larvae at Water Intakes Using Wedge-Wire Screening	Heuer, John H. and David A. Tomljanovich	1978	RKG	The study of the ability of several species of larval fish to avoid impingement on a wedge wire screen.
82	New $7.4 Million Fish Bypass System Being Installed at Wanapum Dam	Northwest Public Power Association (NWPPA) Bulletin (unauthored)	1995	SRT	Article on the Wanapum fish bypass system prototype recently installed.
83	The Use of Floating Louvers for Guiding Atlantic Salmon Smolts from Hydroelectric Turbine Intakes	Ruggles, C.P., D.A. Robinson and R.J. Stira	~1991	RKG	Deals with the use of louvers to guide fish.
84	Fisheries Handbook of Engineering Requirements and Biological Criteria	Bell, Milo C.	1986	RKG	Detailed account of biological criteria for fish species of the Pacific Northwest.
85	Fishways - An Assessment of Their Development and Design	Powers, P.D., J.F. Orsborn, T.W. Bumstead, S. Klinger-Kingsley, W.C. Mih	1985	RKG	Detailed fishway engineering and design information for upstream migrant fish.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
86	Use of a Fish Transportation Barge for Increasing Returns of Steelhead Imprinted for Homing	Harmon, Jerrel R. and Emil Slatick	1989	RKG	Study conducted in 1982 and 1983 to determine numbers of fish that return to spawn when they are barged and released downstream of Bonneville Dam.
87	Little Naches River Passage Project	Woods, Dianna and Kent N. Russell	1990	RKG	This report documents the monitoring and maintenance work for the Little Naches River Passage Project. The projects goal was to provide salmonid access to an additional 24 miles of stream habitat in the Little Naches River and its tributaries.
88	Evaluation of Juvenile Fish Bypass and Adult Fish Passage Facilities at Three Mile Falls Dam, Umatilla River	Nigro, Anthony A.	1989	RKG	Evaluation of the juvenile bypass facilities (drum screens) and the adult passage facilities at Three Mile Falls Dam, Umatilla River.
89	Monitoring of Downstream Salmon & Steelhead at Federal Hydroelectric Facilities	Hawkes, Lynette A., Rick D. Martinson and Randall F. Absolon	1992	RKG	NMFS injury, descaling and mortality monitoring of downstream migrant juvenile fish at John Day and Bonneville Dams.
90	Flow Augmentation and Reservoir Drawdown: Strategies for Recovery of Threatened and Endangered Stocks of Salmon in the Snake River Basin: Technical Report 2 of 11	Giorgi, Albert E.	1993	RKG	Focus' on treating two smolt responses that can be useful in reflecting the effects of flow augmentation, or increased water velocity; travel time or migration speed and survival.
91	Transportation as a Means of Increasing Wild Juvenile Salmon Survival: Technical Report 4 of 11	Park, D.L.	1993	RKG	Report supporting the need for transporting juvenile salmon.
92	Juvenile Passage Program: A Plan for Estimating Smolt Travel Time and Survival in the Snake and Columbia Rivers	Skalski, John R. and Albert Giorgi	1993	RKG	This report presents a plan for developing a program to evaluate juvenile salmon passage at the Lower Snake and Mid- and Lower Columbia River Projects. The plan focuses on the use of PIT- tag technology.
93	Evaluation of Juvenile Fish Bypass and Adult Fish Passage Facilities at Water Diversions in the Umatilla River	Knapp, Suzanne M.	1993	RKG	Evaluation of the juvenile fish bypass and adult passage facilities for the projects in the Lower Umatilla River.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
94	Preliminary "Post-Prototype" Conceptual Designs for the Wanapum Dam Surface Bypass and Collection System	Sverdrup Corporation	1995	RVD	Document summarized in Summary No. 14
95	Elkhorn Hydroelectric Project, Exhibit F-2, "Intake Structure"	Hosey & Associates Engineering Company	1988	RKG	General layout of a traveling belt fish screen.
96	1992 Reservoir Drawdown Test, Lower Granite and Little Goose Dams	USACE: Wik, S., A. Shoudlers, L. Reese, D. Hurson, T. Miller, L. Cunningham, J. Leier, L. Mettler, P. Poolman, J. Buck, C. Wolff J. Smith	1993	RKG	A test of the reservoir drawdown concept was completed in March 1992, using Lower Granite and Little Goose Dams on the lower Snake River. The test was designed to gather information regarding the effects of lowering existing reservoirs substantially - to potentially improve survival of downstream migrating juvenile salmon, as proposed by various entities in the Pacific Northwest.
97	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Main Report - Draft	USACE	1994a	RKG	The System Configuration Study (SCS) is assessing various possible alternatives for improving survival of anadromous fish, both juveniles and adults, migrating through the lower Columbia and Snake River dams and reservoirs. Phase I is a reconnaissance level assessment of alternatives, which were identified in the NPPC *Strategy for Salmon*.
98	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix A - Lower Snake Reservoir Drawdown Technical Report - Draft	USACE	1994b	RKG	This report is a comprehensive evaluation of proposed lower Snake reservoir drawdown alternatives. It includes engineering-related issues, environmental and socioeconomic impacts, and mitigation opportunities.
99	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix B - John Day Reservoir Minimum Operating Pool Technical Report - Draft	USACE	1994c	RKG	This report presents the results of a reconnaissance study of a proposal to operate John Day at its minimum operating pool (MOP) for the benefit of migrating juvenile anadromous fish.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
100	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix C - Additional Snake River Basin Storage Technical Report - Draft	USACE	1994d	RKG	This report presents the status of the Galloway Project study. The report also presents a summary of the findings from the BOR-led interagency upstream storage study.
101	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix D - Upstream Collection and Conveyance Snake and Columbia Rivers Technical Report - Draft	USACE	1994c	RKG	This report examines options that might reduce juvenile salmonid losses that result from migration through the existing hydropower dams and reservoirs on the Snake and Columbia River system.
102	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix E - Improvements to the Existing Systems Technical Report - Draft	USACE	1994f	RKG	This reconnaissance-level study focuses on improvements to fish hatcheries, juvenile fish collection and bypass systems, juvenile fish transportation systems, adult passage systems, and modifications to the dams.
103	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix F - System Improvements Technical Report Lower Columbia River - Draft	USACE	1994g	RKG	This report presents preliminary information on possible improvements to existing lock and dam projects on the lower Columbia River operated by the U.S. Army Corps of Engineers, Portland District.
104	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix G - Biological Plan--Lower Snake River Drawdown Technical Report - Draft	Battelle Pacific NW Laboratories for USACE	1994	RKG	The study examines improvements designed to enhance the survival of anadromous fish. Background information on the decline of the species is also presented.
105	Draft - Lower Snake and Columbia Rivers Surface Bypass and Collection Systems Prototype Development Program	USACE	1994h	RKG	The purpose of this program is to develop and evaluate surface bypass and collection prototype concepts that may lead to permanent systems for improving survival of juvenile salmon migrating past Lower Snake and Columbia Rivers hydroelectric projects operated by the Corps.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
106	Lower Granite Lock and Dam - Surface Collector Prototype Drawings	USACE	1995a	RKG	N/A - This concept was not used.
107A	Notes from Discussions of Bypass Systems and Guidance Equipment - Rocky Reach Hydroelectric Project	Rickman, Eldon (PUD No.1 of Chelan County)	1992	SRT	Documents meeting discussions between Mr. Rickman and Mr. Bob Parka of NMFS regarding orifice hydraulic and cleaning criteria, trashrack proximity recommendations, bypass conduit criteria, and dewatering screen criteria for design of juvenile fish bypass system.
107B	Notes of Meeting on Fish Bypass System Study - Rocky Reach Hydroelectric Project	Makarechian, Hassan/SWEC	1992	SRT	Meeting notes discussing performance of the 60 degree corner orifice leading to a discharge pipe in the pier that releases fish into the collection channel and to review arrangements developed by Stone & Webster for the control and dewatering facilities.
107C	Copy of U.S. Corps of Engineers (Walla Walla District) Juvenile Fishway Design Criteria for Lower Monumental Dam Permanent Fish Facilities	Reese, Lynn (USACE Walla Walla)	1989	SRT	Contains design criteria used by COE for Lower Monumental Dam juvenile fish passage facilities.
108	Final Study Report - Downstream Migrant Fish Bypass System - Rocky Reach Hydroelectric Project	SWEC	1992	SRT	Final report presenting two alternative arrangements of the fingerling bypass system at Rocky Reach Dam. Dewatering proposed using low velocity floor screens for both alternatives.
109	Fingerling Bypass System Study - Rocky Reach Hydroelectric Project	SWEC	1990	RKG	Design information for incorporating a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rocky Reach.
110	Conceptual Drawings for Fish Bypass and Dewatering System - Rock Island Hydroelectric Project	SWEC	1994	RKG	Design information for incorporating a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rock Island.
111	First Powerhouse Fish Guidance and Bypass Equipment Preliminary Cost Estimate - Rock Island Hydroelectric Project	SWEC	1989	RKG	Preliminary cost estimate for a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rock Island.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
112	Pertinent Data from Water Control Manual for Lower Granite Lock and Dam	USACE	1987a	SRT	Technical data for lock and dam facilities including fish facilities.
112A	Design Criteria/Considerations/Questions for Surface Bypass and Collection System Prototype at Lower Granite Dam	Reese, Lynn (USACE - Walla District)	March 1995a	RKG	Design criteria / considerations for Lower Granite's surface bypass and collection facility.
112B	Lower Granite Prototype Development: Preliminary Plan for Tests in 1996	USACE - Walla Walla District	February 1995b	RKG	Preliminary plans for Lower Granite's surface collector and guidance curtain.
112C	Preliminary Design Drawings for Lower Granite Dam Surface Collector Module	USACE - Walla Walla District	March 1995c	RKG	Preliminary plans for Lower Granite's modular surface collector.
112D	Notes of Dewatering System Concepts for Lower Granite Dam Surface Bypass and Collection System Prototype	Reese, Lynn (USACE - Walla Walla District)	April 1995b	RKG	Presents three concepts for location of surface collector; 1) located in front of Units 4-6, 2) located in front of Units 1-3, 3) covering full width of powerhouse. All options consider release of excess water by gravity, pump-back or route through turbine.
112E	Excerpts from Water Control Manual for Lower Granite Lock and Dam	USACE	1987b	RKG	Detailed pertinent data for Lower Granite Lock and Dam.
113	Pertinent Data from Water Control Manual for Little Goose Lock and Dam	USACE	1988a	RKG	Technical (pertinent) data from "Water Control Manual for Little Goose Lock and Dam".
113A	Preliminary Hydraulic Analysis - Revised Design of the Primary Dewatering System at Little Goose Dam Permanent Juvenile Fish Facilities	USACE	September 1988b	RKG	Technical data for the existing fish bypass and collection facilities.
113B	Letter Supplement No. 1 - Changes to Permanent Juvenile Fish Facilities for Little Goose Lock and Dam	USACE	Unknown a	RKG	Describes changes to the permanent fish passage facilities and justifications for the changes.
113C	Revised Design Drawings of the Primary Dewatering System at Little Goose Dam	USACE	August 1988c	RKG	Revised design drawings for the collection channel and primary dewaterer.

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113D	Design Drawings of the Permanent Juvenile Fish Facilities Phase II Primary Dewatering System at Little Goose Dam	USACE	January 1989a	RKG	System configuration drawings for the primary dewatering facility.
114	Pertinent Data from Water Control Manual for Lower Monumental Lock and Dam	USACE	1987c	RKG	Technical (pertinent) data from "Water Control Manual for Lower Monumental Lock and Dam".
114A	Lower Monumental Juvenile Fish Bypass Water-Up Plan	USACE	Unknown b	RKG	Description of the water-up and normal operation of the collection gallery, dewatering structure, downstream flume and drain to the adult fish ladder.
114B	Design Drawings for Permanent Juvenile Fish Bypass Primary Dewatering System for Lower Monumental Dam	USACE	August 1990a	RKG	System configuration drawings for the primary dewatering facility.
115	Pertinent Data from Water Control Manual for McNary Lock and Dam	USACE	1989b	RKG	Technical (pertinent) data from "Water Control Manual for McNary Lock and Dam".
115A	Hydraulic Design Section from McNary Dam	USACE	Unknown c	RKG	Hydraulic design criteria for the McNary juvenile fish facility.
115B	Design Drawings for Permanent Juvenile Fish Facilities Primary Dewatering At McNary Dam	USACE	November 1990b	RKG	System configuration drawings for the collection channel and primary dewaterer.
115C	Water-Up Schematic for Permanent Juvenile Fish Facilities at McNary Dam	USACE	February 1994i	RKG	Water-up schematic for the collection channel and transportation flume.
116	Phone Memo/Trip Report of USACE/PUD Smolt Bypass Workshop	Kurkjian, Donald/SWEC	April 1994	RKG	Overview of smolt bypass workshop which focused on surface collection and fish guidance efficiency.
117	Wedge-Wire Kleenslot Preparation Screens - Catalog No. 105	Wedge-Wire Corporation, Wellington, Ohio	Unknown	SRT	Technical data for wedge-wire screens.

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117A	Bee-Zee Screen Catalog	Bixby-Zimmer Engineering Co., Galesburg, Illinois	Unknown	SRT	Technical data for Bee-Zee screens.
117B	Specification Tables for C-E Tyler Industrial Wire Cloth and Woven Wire Screens - Catalog No. 74	Combustion Engineering	1987	SRT	Technical data for industrial wire cloth and woven wire screens.
118	DRAFT Fish Bypass Annual Project Team Report for Period Ending December 1994	Chelan County Public Utility District	February 1995	SRT	Summary document discussing District's activities for Rocky Reach and Rock Island Dams to-date in testing of passive fish diversion screens, development of surface fish attraction prototypes and future anticipated activities including testing and development of fish-friendly turbines.
119	Selected General Design Drawings of Wapatox Canal Diversion Fish Screen Facilities	James M. Montgomery Consulting Engineers, Inc. and Pacific Power & Light	Unknown	SRT	Facility toured and inspected in field on morning of May 3, 1995. Copy of a portion of three (3) design drawings provided.
120	Selected Design Drawings of The Dalles Dam North Shore Fishway	CH2M Hill and Northern Wasco County P.U.D.	July 1989	SRT	Facility toured and inspected in field on afternoon of May 3, 1995. Copy of eight (8) design drawings provided.
121	Fish Diversionary Techniques for Hydroelectric Turbine Intakes Research Report	Canadian Electrical Association	January 1984	PLJ	**Document summarized in Summary No. 15**
122	A Guidance Manual for the Input of Biological Information to Water Intake Structure Design	Neitzel, D.A., M.A. Simmons, and D.H. McKenzie	December 1981	PLJ	Guide to consideration of biological, hydraulic, water quality, and habitat influence in selection of intake designs and locations. Document is conceptual and thus offers no direct application direction.

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123	Procedure for Developing Biological Input for the Design, Location or Modification of Water Intake Structures	Neitzel, D.A. and D.H. McKenzie	December 1981	PLJ	Expansion on the previous document. Gives examples and insight into application. Although oriented at organism exclusion it is equally applicable to increasing collection/passage efficiency. Although still conceptual, gives considerable insight into intake design and siting. Cites numerous references on site and species specific influences on entrainment.
124	Evaluation of Models for Developing Biological Input for the Design and Location of Water Intake Structures	Simmons, M.A. and D.H. McKenzie	December 1981	PLJ	Follow up to documents 122 and 123. Presents decision making structure that guides assessment of multiple stimulus/response relationships in intake design and selection.
125	Development of Biological Criteria for Siting and Operation of Juvenile Fish Bypass Systems: Implications for Protecting Juvenile Salmonids from Predation	Poe, Thomas P., Matthew G. Mesa, Rip S. Shively, and Rock D. Peters	September 1993	PLJ	Addresses predation as a function of bypass out-fall location. Notes that predation can negate positive benefits of the bypass. Implies that eddy free dewatering systems operating with internal velocities of 100 to 130 cm/s will minimize resident squawfish predation.
126	Impacts of Power Plant Intake Velocities on Fish	Boreman, John	March 1977	PLJ	Overview of the relationship between intake velocities and associated juvenile fish entrainment or impingement. Largely oriented at issues associated with larval and post-larval exclusion.
127	A Fish Protection Facility for the Proposed Peripheral Canal	Odenweller, Dan and Randall Brown	April 1981	PLJ	Summary of document number 168.
128	Preliminary Studies on the Operating Aspects of Small Slot-Width Wedgewire Screens on the Chesapeake and Delaware Canal with Conceptual Designs for Power Station Usage	Key, Thomas H. and John C. Miller	November 1977	PLJ	Prototype evaluation of 1 mm slot width cylindrical wedge-wire screens for larval fish exclusion. Shows growth on screens to be biggest maintenance problem. Suggests use of copper bearing materials to reduce biofouling but notes that manual cleaning will be required.

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129	Practicality of Profile Wire Screen in Reducing Entrainment and Impingement	Hanson, Brian N., William H. Bason, Barry E. Beitz, and Kevin E. Charles	February 1978	PLJ	Extensive prototype striped bass egg, larvae, and juvenile fish exclusion and impingement studies of 1.01 mm slot width cylindrical wedge-wire screens. Effective exclusion with minimal impingement was achieved for approach velocities of 15 to 53 cm/s. Fouling studies show good self-cleaning however removal of growth on the screens required physical cleaning.
130	Fish Screen Head Loss - Perforated 16-Gage Steel Plate (5/32-inch Holes Staggered on 7/32-inch Centers) Versus 5-Mesh, 19-Gage Galvanized Wire - Tracy Pumping Plant Intake - Central Valley Project	Karrh, Wiley J., W.C. Case and J.W. Ball (USBR Hydraulic Laboratory Report No. Hyd-274)	March 1950	PLJ	Head loss evaluation with normal and 45° angles of approach. Perforated plate has 46% open area and woven screen has 66% open area. Head losses through the woven screen averaged less than 10% of head losses through the perforated plate. Materials do not satisfy current criteria but tend to show the high head loss characteristics of perforated plate.
131	Investigations on the Protection of Fish Larvae at Water Intakes Using Fine-Mesh Screening	Tomljanovich, David A., John H. Heuer and Clyde W. Voigtlander	February 1977	PLJ	Evaluation of larval fish exclusion characteristics of woven screen. Not applicable to this study.
132	A Passive Fish Screen for Hydroelectric Turbines	Eicher, George J.	1982	PLJ	Initial documentation on the Eicher screen at Portland General Electric's Sullivan plant. Largely contains background information.
133	Innovative Fish Barrier for Waterfowl Lake Restoration	Strong, James	1989	PLJ	Review of screening options for larval fish exclusion. General discussion of development of a Coanda effect screen.
134	Passage of Juvenile Chinook Salmon, <u>Oncorhynchus Tshawtscha</u>, and American Shad, <u>Alosa Sapidissima</u>, Through Various Trashrack Bar Spacings	Reading, Harvey H.	October 1982	PLJ	Evaluation of day and night passage of juvenile chinook salmon and American shad through trashracks. 35 to 75 mm chinook passage appeared largely independent of bar spacing (7.6 to 30.5 cm) and dependent on velocities with passage rates declining with a velocity of 30.5 cm/s.
135	Fish Passage at Hydroelectric Projects	Taft, Ned	August 1994	PLJ	Summary of Document Number 2.

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136	River Water Intake with Bypass Flow for Fish Protection	Copeland, Arno, Edward L. Mulvihill, K. Perry Campbell, and Albert G. Mercer	April 1981	PLJ	Presents design and development of a 61 cfs in-river screen. Includes angled trashrack bars which allow maintenance of sweeping velocities past screen faces. The screens are isolated from the atmosphere and can be heated for ice control.
137	1983 Iowa Flume Study of Fish Guidance	Bronoski, Michael and Raymond Vandenberg (USACE Kansas City District)	April 1984	PLJ	Limited relevance. Flume studies show vertical angled screen (25° angle to flow) to yield better guidance than bar racks or louvers. Missouri, non-salmonid species impinged with mortalities (primarily for crappie and gizzard shad) with approach resultant velocities of both 1.0 and 2.0 ft/s.
138	1982 Iowa Flume Study of Fish Guidance	Vandenberg, Raymond, Garland Kersh and Michael Bronoski (USACE Kansas City District)	June 1983	PLJ	Non-salmonid flume study of fixed screens. Resultant approach velocities of 1.0 and 2.5 ft/s were evaluated. 30° inclined screen yielded better guidance than a 20° inclined screen. Good guidance was achieved with resultant approach velocities below 1.5 ft/s. Increased impingement was observed with an approach resultant velocity of 2.5 ft/s. No performance difference between woven inclined screen, wedge-wire inclined screen, and vertical wedge-wire angled screens was noted.
139	Fish Passage: Protection of Downstream Migrants	Eicher, George J.	1985	RKG	General information on fish bypass systems along with passage through turbines and over spillways.
140	Angled Screens and Louvers for Diverting Fish at Power Plants - Journal of the Hydraulics Division ASCE	Taft, Edward P. III and Yusuf G. Mussalli/SWEC	May 1978	RKG	Discussion on the pro's and con's of louver systems as compared to angled screens. Identifies projects and studies which apply to both systems.
141	EPRI's Evaluation of the Elwha Dam Eicher Screen and Subsequent Design Changes and Hydraulic Tests	Winchell, Fred, Ned Taft, Tom Cook, and Charles Sullivan/SWEC	September 1993	RKG	See Document No. 19. Same information given.
142	A New Technology for Diverting Fish Past Turbines	Winchell, Fred C./SWEC	December 1990	RKG	Older version of Document No. 25.

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143	Water Velocities in Relation to Fish Behavior in the Design of Screens for Diversion of Juvenile Salmonids from Turbines at Hydroelectric Dam on the Columbia River, U.S.A.	Williams, John G./SWEC	1990	RKG	Provides design information which correlates velocity to fish behavior on submerged traveling screens currently in use at many of the Lower Snake and Columbia River Projects.
144	Some Design Considerations for Approach Velocities at Juvenile Salmonid Screening Facilities	Parka, Robert O. and Randall T. Lee	1991	RKG	**Document summarized in Summary No. 17.**
145	An Inclined-Screen Smolt Trap with Adjustable Screen for Highly Variable Flows	DuBois, Robert B., John E. Miller and Scott D. Plaster	1991	RKG	Provides information on an inexpensive inclined screen smolt trap for use in rivers having highly variable flow regimes.
146	Report on the Loss of Salmonid Fish at the Winchester Hydroelectric Project in 1984	Williams, Ron	June 1985	RKG	This report attempted to place a monetary value on both adult and juvenile fish lost after bypass system installation and fish ladder rehabilitation at the Winchester Hydroelectric Project.
147	Evaluation of Fish-Passage Facilities at the North Fork Project on the Clackamas River in Oregon	Gunsolus, Robert T. and George J. Eicher	September 1970	RKG	Evaluation of the fish facilities of the North Fork Project for upstream and downstream migrant fish studied from 1962 to 1964.
148	Biological Basis of Protecting Fish from Entry Into Water Intake Structures	Pavlov, D.S. and A.M. Pakhorukov	May 1974	PLJ	Review of Russian and western fish behavior and screening activities. Document includes discussion of fish behavior, swimming characteristics, intake placement, screening concepts, and behavioral fish exclusion techniques. The biological data is extensive. Unique screening concepts addressed include conical pressure screens (similar to Eicher and MIS) that use screen rotation for cleaning and a well concept that uses avoidance of sounding for fish exclusion.
149	Fish Barrier Dams	Wagner, Charles H.	August 1967	RKG	Fish barrier dam were designed in the '60s due to the difficultly in maintaining fish rack barriers during heavy debris loading.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
150	Field Evaluation of Passive Bar Screens for Guiding Juvenile Salmonids Out of Turbine Intakes of Hydroelectric Dams	Krcma, Richard F., Winston E. Farr and Clifford W. Long	Unknown	RKG	Discusses the implementation of bar screens in turbine intakes to replace submersible traveling screens.
151	Considerations in the Design of Juvenile Bypass Systems	Rainey, William S.	May 1985	RKG	This paper emphasizes the importance of the bypass system in protecting juvenile fish at screen facilities. Screen/bypass layouts, juvenile behavior, and hydraulic considerations are addresses, followed by a discussion of key elements of the bypass design.
152	Fish Impingement Studies at the Hanford Generating Project (HGP) December 1975 through April 1976	Page, T.L., R.H. Gray and D.A. Neitzel	August 1976	RKG	This report covers HGP's efforts to modify traveling screens with buckets and a backwash system to prevent impinged juvenile fish from being killed.
153	Hydraulic Model Evaluation of the Eicher Passive Pressure Screen Fish Bypass System	EPRI	October 1987	RKG	**Document summarized in Summary No. 18.**
154	Evaluation of Two Concepts for Protection of Fish Larvae at Cooling Water Intakes	Tomljanovich, D.A., J.H. Heuer, M. Smith, P. Smith, S. Vigander, R. Whitaker, J.B. Brellenthin, J.T. Johnson, and S.H. Magliente	May 1980	RKG	This report details laboratory investigations on the impinge-release and avoidance concepts for protection of larval fish at cooling water intakes.
155	Fish Protection with Wedge Wire Screens at Eddystone Station	Veneziale, Edward J.	Unknown	RKG	Discusses the installation of circular wedge-wire screens replacing the traveling screens at the cooling water intake. The system included an air backflush system which eliminated fish impingement and screen fouling.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
156	Monitoring of Downstream Salmon and Steelhead at Federal Hydroelectric Facilities - 1986	Johnson, Richard C., Lynette A. Wood and W. William Smith	December 1986	RKG	The 1986 smolt monitoring project of the NMFS provided data on the seaward migration of juvenile salmon and steelhead at Lower Granite Dam, Lower Monumental Dam, McNary Dam, John Day Dam and Bonneville Dam. The number of fish sampled by species, brand recaptures and pertinent flow data were provided for the Fish Passage Center for the purpose of evaluating smolt survival, travel time and migration timing.
157	Bypass and Collection System for Protection of Juvenile Salmon and Trout at Little Goose Dam	Smith, Jim Ross and Winston E. Farr	February 1975	RKG	Describes the physical characteristics, operation and effectiveness of the fish passage facilities at Little Goose Dam as of 1975.
158	Experiments Related to Directing Atlantic Salmon Smolts (Salmo salar) Around Hydroelectric Turbines	Semple, J. Richard and Curtis L. McLeod	September 1976	RKG	Discussion on testing of turbine intake screening done at a hydroelectric dam on the Tusket River, Nova Scotia in 1976. It was concluded that smolt guidance efficiency is positively dependent on deeper screening depths and reduced angle of deflection. The most efficient deflector array for smolt guidance of those tested was one in which the screens were operated at a depth of 2.44 m without a sounding lip and at an angle of 45° to the flow.
159	Downstream Migration Facilities and Turbine Mortality Evaluation, Atlantic Salmon Smolts at Malay Falls, Nova Scotia	Semple, J.R.	October 1979	RKG	Fish passage studies were conducted at Malay Falls Hydroelectric Dam, on East River, Sheet Harbour, Nova Scotia. Test fish were hatchery-reared Atlantic salmon smolt with a fork length equal to or greater than 15 cm. Turbine mortality, downstream passage rate and efficiency of a surface bypass were evaluated. Turbine mortality averaged 10.6±2.3% and was reduced to 5.1 to 5.7% of the total emigrant smolt by operation of a surface bypass without a forebay fish deflector.
160	Research on a System for Bypassing Juvenile Salmon & Trout Around Low-Head Dams	Long, Clifford W. and Richard F. Krcma	June 1969	RKG	Early report on the first attempts made by BCF and USACE to protect juvenile fish by means of intake screens and transportation around the dams.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
161	Traveling Screens for Turbine Intakes of Hydroelectric Dams	Farr, Winston E.	Unknown	RKG	General paper on the development of submerged traveling screens.
162	Fish-Bypass Experience at PGE's New Hydro Projects	Eicher, George J.	March 1960	RKG	Reports on PGE's development of skimmer technology in the 1950's.
163	Fish Get Novel Treatment at PGE's North Fork Project	Eicher, George J.	April 1958	RKG	Early report on Portland General Electric's North Fork hydroelectric project includes a fingerling bypass five miles in length, a two mile fish ladder bypassing two dams and a structure to separate upstream and downstream migrant fish in the ladder.
164	Turbine Screen for Downstream Migrating Fish	Miller, Donald R.	1984	RKG	General report on PGE's efforts to develop a turbine screen to bypass juvenile fish.
165	Evaluation of Downstream Migrant Bypass System - T. W. Sullivan Plant, Willamette Falls	Cramer, Douglas P.	October 1982	RKG	Presents test results to evaluate the T. W. Sullivan Plant, Willamette Falls juvenile fish bypass system. Average bypass efficiencies for spring chinook 89.7%, fall chinook 95.9% and steelhead 81.5%.
166	Hydraulic Design of Angled Drum Fish Screens	Johnson, Perry J.	1988	PLJ	Reviews parameters influencing velocity distributions through angled screens. Notes that distributions strongly depend on approach flow distribution, screen alignment, and potential distribution (which is in turn dependent on sink geometry and back wash influences in the discharge channel. The paper is broadly applicable to angled screen designs.

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167	Modular Fish Screen Hydraulic Model Study	Kubitschek, Joseph	1995	PLJ	A hydraulic model study is used to develop porosity control or internal vanes to generate uniform through screen velocity distributions for a fixed horizontal screen module. The vanes, which modified the internal sink characteristics, were found to be both awkward and ineffective. Use of a variable porosity, perforated plate yielded effective porosity and velocity distribution control. The modular screen requires additional development (cleaning system, installation details, biological effectiveness evaluation) prior to general application.
168	Delta Fish Facilities Program Report Through June 30, 1982	Odenweller, Dan B. and Randall L. Brown	1982	PLJ	Summarizes field and laboratory work conducted by the State of California in developing a fish exclusion system for the proposed Peripheral Canal. Proposes a positive barrier screen using 2.4 mm slot width wedge-wire. Concludes that 6.1 cm/s is an appropriate design approach velocity for fry and juvenile American shad and chinook salmon. Proposes selective curtailment of diversion for larval fish exclusion. Studies evaluate cleaning, corrosion, clogging, swimming performance, and screen opening size selection.
169	Use of Behavioral Stimuli to Divert Sockeye Salmon Smolts at the Seton Hydro-Electric Station, British Columbia	McKinley, R.S. and P.H. Patrick	1988	PLJ	Field evaluation of behavioral techniques for preventing fish entrainment at a hydro-electric station. A hammer device showed 75% fish exclusion efficiency, a popper showed 66% efficiency, and strobes showed 56% efficiency. Strobe efficiencies varied with species, size, and time of day.
170	E-Mail Correspondence Between Ken Bates and Darryl Hayes of the California Department of Water Resources	Bates, Ken and Darryl Hayes	April 1995	PLJ	E-mail communication between Ken Bates of the Washington Department of Fish and Wildlife and Darryl Hayes of the California Department of Water Resources discussing screening velocity criteria. Use of this document was cleared through Bates. Document supplies justification for the NMFS juvenile screening criteria. High velocity criteria is identified as developmental, warranting further research.

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49	Development of an Eicher Screen at the Elwha Dam Hydroelectric Project	Adam, P., S.P. Jarrett, A.C. Solonsky and L. Swenson	1991	RKG	Eicher screens are penstock applications. Basic screen concepts may be helpful in dewatering system design. Wedge-wire screen manufactured by Hendrick Screen Co., porosity varied from 8% upstream to 63% downstream, which results in fairly uniform normal velocity component for the entire length of screen.
66	Design and Operation of an Angled Screen Intake Structure with Protective Features for Fish and Facilities for Fish Monitoring	Anderson, M.R., J.A. Divito and Y.G. Mussalli/SWEC	1984	RKG	Detailed discussion on power plant cooling water intake fish protection for the Brayton Point Generating Station. Traveling angled screens are used to guide fish to a bypass. Some fish are impinged on the traveling screens and washed off the backside into a fish trough.
12	Water Intake Structures Design for Fish Protection	ASCE Committee on Hydraulic Structures	1981	RKG	Not relevant. Fish protection for cooling water intakes are based on four concepts; Fish collection and removal, Fish diversion, Fish deterrence and Physical exclusion. Focus of paper is on bucket type traveling screens which impinge fish and back wash them into a collection channel. Minor discussion on angled screens.
50	Design of Extended Length Submerged Traveling Screen and Submerged Bar Screen Fish Guidance Equipment	Bardy, D., M. Lindstrom and D. Fechner	1991	RKG	Debris is cleaned from the submerged bar screens by brushes attached to roller chains. Cleaning is done every 15 minutes. Document gives overview of the Extended Submerged Bar Screens (ESBS) and difficulties of design and implementation.
170	E-Mail Correspondence Between Ken Bates and Darryl Hayes of the California Department of Water Resources	Bates, Ken and Darryl Hayes	April 1995	PLJ	E-mail communication between Ken Bates of the Washington Department of Fish and Wildlife and Darryl Hayes of the California Department of Water Resources discussing screening velocity criteria. Use of this document was cleared through Bates. Document supplies justification for the NMFS juvenile screening criteria. High velocity criteria is identified as developmental, warranting further research.

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104	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix G - Biological Plan--Lower Snake River Drawdown Technical Report - Draft	Battelle Pacific NW Laboratories for USACE	1994	RKG	The study examines improvements designed to enhance the survival of anadromous fish. Background information on the decline of the species is also presented.
84	Fisheries Handbook of Engineering Requirements and Biological Criteria	Bell, Milo C.	1986	RKG	Detailed account of biological criteria for fish species of the Pacific Northwest.
117A	Bee-Zee Screen Catalog	Bixby-Zimmer Engineering Co., Galesburg, Illinois	Unknown	SRT	Technical data for Bee-Zee screens.
73	Evaluation of a Louver Array/Bypass System in Bypassing Atlantic Salmon Smolts from the Holyoke Canal to the Connecticut River	Boltz, Jeffrey M., David A. Robinson, Robert J. Stira, and Paul Ruggles	1993	RKG	Evaluation of louver arrays to guide atlantic salmon smolts from the Holyoke Canal. Studies indicate that louvers are an effective means of diverting up to 80% of the smolts.
126	Impacts of Power Plant Intake Velocities on Fish	Boreman, John	March 1977	PLJ	Overview of the relationship between intake velocities and associated juvenile fish entrainment or impingement. Largely oriented at issues associated with larval and post-larval exclusion.
137	1983 Iowa Flume Study of Fish Guidance	Bronoski, Michael and Raymond Vandenberg (USACE Kansas City District)	April 1984	PLJ	Limited relevance. Flume studies show vertical angled screen (25° angle to flow) to yield better guidance than bar racks or louvers. Missouri, non-salmonid species impinged with mortalities (primarily for crappie and gizzard shad) with approach resultant velocities of both 1.0 and 2.0 ft/s.
75	Examining the Benefits and Costs of Fish Passage and Protection Measures	Cada, Glenn F. and James E. Francfort	1995	RKG	Using 16 U.S. hydroelectric projects as case studies, researchers have determined that fish passage/protection mitigation measures are generally effective. This paper examines the total cost of mitigation on a mills/Kwh basis.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
121	Fish Diversionary Techniques for Hydroelectric Turbine Intakes Research Report	Canadian Electrical Association	January 1984	PLJ	**Document summarized in Summary No. 15**
120	Selected Design Drawings of The Dalles Dam North Shore Fishway	CH2M Hill and Northern Wasco County P.U.D.	July 1989	SRT	Facility toured and inspected in field on afternoon of May 3, 1995. Copy of eight (8) design drawings provided.
61	Rocky Reach Fish Guidance 1995 Prototype - Construction Drawings	CH2M Hill	1994	SRT	Facility toured and inspected on morning of May 1, 1995.
118	DRAFT Fish Bypass Annual Project Team Report for Period Ending December 1994	Chelan County Public Utility District	February 1995	SRT	Summary document discussing District's activities for Rocky Reach and Rock Island Dams to-date in testing of passive fish diversion screens, development of surface fish attraction prototypes and future anticipated activities including testing and development of fish-friendly turbines.
36	Design of Fishways and Other Fish Facilities	Clay, Charles H.	1995	RVD	**Document summarized in Summary No. 11.**
117B	Specification Tables for C-E Tyler Industrial Wire Cloth and Woven Wire Screens - Catalog No. 74	Combustion Engineering	1987	SRT	Technical data for industrial wire cloth and woven wire screens.
22	Hydraulics of a New Modular Fish Diversion Screen	Cook, T.C., E.P. Taft, G.E. Hecker, and C.W. Sullivan/SWEC	1993	RKG	**Document summarized in Summary No. 8.**
7	The Johnson Screen for Cooling Water Intakes	Cook, Lee E.	Unknown	SRT	Examines velocity distributions around pipe screens.
136	River Water Intake with Bypass Flow for Fish Protection	Copeland, Arno, Edward L. Mulvihill, K. Perry Campbell, and Albert G. Mercer	April 1981	PLJ	Presents design and development of a 61 cfs in-river screen. Includes angled trashrack bars which allow maintenance of sweeping velocities past screen faces. The screens are isolated from the atmosphere and can be heated for ice control.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
165	Evaluation of Downstream Migrant Bypass System - T. W. Sullivan Plant, Willamette Falls	Cramer, Douglas P.	October 1982	RKG	Presents test results to evaluate the T. W. Sullivan Plant, Willamette Falls juvenile fish bypass system. Average bypass efficiencies for spring chinook 89.7%, fall chinook 95.9% and steelhead 81.5%.
69	Fish Passage and Hydropower Development at the Dalles Dam	DeHeer, Lee	1993	RKG	This paper details the retrofit of The Dalles Dam North Shore Fishway with an Attraction Water Supply System. The system consists of an underground powerhouse with a single 5 MW Francis unit which discharges 800 cfs directly into the fish ladder to provide fish attraction flow.
57	Fish Screens for Hydropower Developments	Dorratcague, D.E., G.R. Leidy and R.F. Ott	1985	RKG	This document presents older screening technologies (inclined plane, vertical perforated plate, Coanda, circular, and submersible traveling screens) in general terms.
26	Net and Hydroacoustic Monitoring of Fish Passage	Downing, John, Paul Martin, Ned Taft, and Charles Sullivan/SWEC	1991	RKG	Not relevant. Hydroacoustic systems generally over-count the numbers of fish passed relative to the number of fish collected downstream in the collection net.
145	An Inclined-Screen Smolt Trap with Adjustable Screen for Highly Variable Flows	DuBois, Robert B., John E. Miller and Scott D. Plaster	1991	RKG	Provides information on an inexpensive inclined screen smolt trap for use in rivers having highly variable flow regimes.
163	Fish Get Novel Treatment at PGE's North Fork Project	Eicher, George J.	April 1958	RKG	Early report on Portland General Electric's North Fork hydroelectric project includes a fingerling bypass five miles in length, a two mile fish ladder bypassing two dams and a structure to separate upstream and downstream migrant fish in the ladder.
162	Fish-Bypass Experience at PGE's New Hydro Projects	Eicher, George J.	March 1960	RKG	Reports on PGE's development of skimmer technology in the 1950's.
132	A Passive Fish Screen for Hydroelectric Turbines	Eicher, George J.	1982	PLJ	Initial documentation on the Eicher screen at Portland General Electric's Sullivan plant. Largely contains background information.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
139	Fish Passage: Protection of Downstream Migrants	Eicher, George J.	1985	RKG	General information on fish bypass systems along with passage through turbines and over spillways.
56	Development of Turbine Intake Downstream Migrant Diversion Screen	Elder, R.A., A.J. Odgaard, W. Weitkamp and D. Zeigler	1987	RKG	Details development of submerged bar screens.
63A	Briefing Document for June 7, 1994 Workshop at ENSR Consulting and Engineering on Flow Attraction Alternatives for Juvenile Fish Bypass at Rocky Reach Dam	ENSR Consulting and Engineering	May 1994b	SRT	Summary of field and model observations of forebay hydraulics and fish movement, site specific theory of fish behavior, and results of various flow attraction alternatives leading to the present leading design alternative.
63	Rocky Reach Dam Juvenile Fish Bypass - Technical Forebay Hydraulic Data	ENSR Consulting and Engineering	1994a	RVD	ENSR constructed a model of the Rocky Reach forebay to determine the existing vectors and their velocities at various flows. The prototype juvenile bypass was installed and tested with the structure in place.
4	Biological Evaluation of a Modular Inclined Screen for Protecting Fish at Water Intakes	EPRI/SWEC	1994c	RKG	**Document summarized in Summary No. 4.**
3	Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application	EPRI/SWEC	1994b	RKG	**Document summarized in Summary No. 3.**
153	Hydraulic Model Evaluation of the Eicher Passive Pressure Screen Fish Bypass System	EPRI	October 1987	RKG	**Document summarized in Summary No. 18.**
2	Research Update on Fish Protection Technologies for Water Intakes	EPRI/SWEC	1994a	RKG	**Document summarized in Summary No. 2.**

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
1	Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application	EPRI/SWEC	1986	RKG	Document summarized in Summary No. 1.
161	Traveling Screens for Turbine Intakes of Hydroelectric Dams	Farr, Winston E.	Unknown	RKG	General paper on the development of submerged traveling screens.
76	Analyzing Turbine Bypass Systems at Hydro Facilities	Ferguson, John W.	1992	RKG	Discussion of a general history of bypass systems at the Columbia and Snake River projects.
77	Improving Fish Survival through Turbines	Ferguson, John W.	1993	RKG	This paper focus' on the studies involved in determining fish mortality when they pass through turbines. Effects of strike, pressure, cavitation, shear, stress and grinding on fish are described.
65-SUM	Protecting Fish (Summary of Document No. 65)	Francfort, J.E. and B.N. Rinehart	1994b	RKG	Summary of Document No. 65. This report documents the mitigation measures in detail, including performance, monitoring practices, benefits and costs at 16 case study projects. Costs were the major concern not the technology of the fish bypass facilities.
65-11	Leaburg Case Study (Section 11 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994c	RKG	Detailed mitigation cost analysis for the Leaburg Project for use in Document No. 65.
65	Environmental Mitigation at Hydroelectric Projects: Volume II - Benefits and Costs of Fish Passage and Protection	Francfort, J.E., G.F. Cada, D.D. Dauble, R.T. Hunt, D.W. Jones, B.N. Rinehart, G.L.Sommers, R.J. Costello	1994a	RKG	See Document No. 65-SUM

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65-12	Little Falls Case Study (Section 12 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994d	RKG	Detailed mitigation cost analysis for the Little Falls Project for use in Document No. 65.
65-23	Summary Table for Downstream Fish Passage/Protection Mitigation (Section 23 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994i	RKG	Table of Downstream fish passage/protection mitigation benefits, levelized annual costs over 20 years (1993 dollars) for use in Document No. 65.
65-20	West Enfield Case Study (Section 20 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994h	RKG	Detailed mitigation cost analysis for the West Enfield Project for use in Document No. 65.
65-19	Wells Case Study (Section 19 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994g	RKG	Detailed mitigation cost analysis for the Wells Project for use in Document No. 65.
65-14	Lower Monumental Case Study (Section 14 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994e	RKG	Detailed mitigation cost analysis for the Lower Monumental Project for use in Document No. 65.
65-17	Twin Falls Case Study (Section 17 from Document No. 65)	Francfort, J.E. et al. (Same as Document No. 65)	1994f	RKG	Detailed mitigation cost analysis for the Twin Falls Project for use in Document No. 65.
90	Flow Augmentation and Reservoir Drawdown: Strategies for Recovery of Threatened and Endangered Stocks of Salmon in the Snake River Basin: Technical Report 2 of 11	Giorgi, Albert E.	1993	RKG	Focus' on treating two smolt responses that can be useful in reflecting the effects of flow augmentation, or increased water velocity; travel time or migration speed and survival.
147	Evaluation of Fish-Passage Facilities at the North Fork Project on the Clackamas River in Oregon	Gunsolus, Robert T. and George J. Eicher	September 1970	RKG	Evaluation of the fish facilities of the North Fork Project for upstream and downstream migrant fish studied from 1962 to 1964.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
55	Protection of Juvenile Anadromous Fish	Haider, T.R. and P.H. Nelson	1987	RKG	Focus is on drum screens.
129	Practicality of Profile Wire Screen in Reducing Entrainment and Impingement	Hanson, Brian N., William H. Bason, Barry E. Beitz, and Kevin E. Charles	February 1978	PLJ	Extensive prototype striped bass egg, larvae, and juvenile fish exclusion and impingement studies of 1.01 mm slot width cylindrical wedge-wire screens. Effective exclusion with minimal impingement was achieved for approach velocities of 15 to 53 cm/s. Fouling studies show good self-cleaning however removal of growth on the screens required physical cleaning.
86	Use of a Fish Transportation Barge for Increasing Returns of Steelhead Imprinted for Homing	Harmon, Jerrel R. and Emil Slatick	1989	RKG	Study conducted in 1982 and 1983 to determine numbers of fish that return to spawn when they are barged and released downstream of Bonneville Dam.
89	Monitoring of Downstream Salmon & Steelhead at Federal Hydroelectric Facilities	Hawkes, Lynette A., Rick D. Martinson and Randall F. Absolon	1992	RKG	NMFS injury, descaling and mortality monitoring of downstream migrant juvenile fish at John Day and Bonneville Dams.
81	A Study on the Protection of Fish Larvae at Water Intakes Using Wedge-Wire Screening	Heuer, John H. and David A. Tomljanovich	1978	RKG	The study of the ability of several species of larval fish to avoid impingement on a wedge wire screen.
95	Elkhorn Hydroelectric Project, Exhibit F-2, "Intake Structure"	Hosey & Associates Engineering Company	1988	RKG	General layout of a traveling belt fish screen.
51	Turbine Intake Modification for Fish Passage	Ismail, F., R. Vaughn and R. Walker	1987	RKG	Not relevant. This paper concentrates on modifying the turbine intake to draw near-surface juveniles down into the turbine intake.
119	Selected General Design Drawings of Wapatox Canal Diversion Fish Screen Facilities	James M. Montgomery Consulting Engineers, Inc. and Pacific Power & Light	Unknown	SRT	Facility toured and inspected in field on morning of May 3, 1995. Copy of a portion of three (3) design drawings provided.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
70	Use of Flexible Curtains to Control Reservoir Release Temperatures - Physical Model and Field Prototype Observations	Johnson, Perry, Tracy Vermeyen, and Greg O'Haver	1993	RKG	The Bureau of Reclamation is developing flexible curtain barriers to control reservoir release water temperatures for structures in the Trinity River and Sacramento River drainages of Northern California.
166	Hydraulic Design of Angled Drum Fish Screens	Johnson, Perry J.	1988	PLJ	Reviews parameters influencing velocity distributions through angled screens. Notes that distributions strongly depend on approach flow distribution, screen alignment, and potential distribution (which is in turn dependent on sink geometry and back wash influences in the discharge channel. The paper is broadly applicable to angled screen designs.
5	Development of a Fixed Horizontal Screen to Prevent Transbasin Fish Transfer	Johnson, Perry L. and Stephen J. Grabowski	1980	SRT	Fish screen sloping down in the downstream direction reduced debris deposition on screen. 70-mesh phosphor bronze screen prevents passage of fish, eggs and larvae. Water jet cleaning system worked well except for algae.
156	Monitoring of Downstream Salmon and Steelhead at Federal Hydroelectric Facilities - 1986	Johnson, Richard C., Lynette A. Wood and W. William Smith	December 1986	RKG	The 1986 smolt monitoring project of the NMFS provided data on the seaward migration of juvenile salmon and steelhead at Lower Granite Dam, Lower Monumental Dam, McNary Dam, John Day Dam and Bonneville Dam. The number of fish sampled by species, brand recaptures and pertinent flow data were provided for the Fish Passage Center for the purpose of evaluating smolt survival, travel time and migration timing.
130	Fish Screen Head Loss - Perforated 16-Gage Steel Plate (5/32-inch Holes Staggered on 7/32-inch Centers) Versus 5-Mesh, 19-Gage Galvanized Wire - Tracy Pumping Plant Intake - Central Valley Project	Karrh, Wiley J., W.C. Case and J.W. Ball (USBR Hydraulic Laboratory Report No. Hyd-274)	March 1950	PLJ	Head loss evaluation with normal and 45° angles of approach. Perforated plate has 46% open area and woven screen has 66% open area. Head losses through the woven screen averaged less than 10% of head losses through the perforated plate. Materials do not satisfy current criteria but tend to show the high head loss characteristics of perforated plate.

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128	Preliminary Studies on the Operating Aspects of Small Slot-Width Wedgewire Screens on the Chesapeake and Delaware Canal with Conceptual Designs for Power Station Usage	Key, Thomas H. and John C. Miller	November 1977	PLJ	Prototype evaluation of 1 mm slot width cylindrical wedge-wire screens for larval fish exclusion. Shows growth on screens to be biggest maintenance problem. Suggests use of copper bearing materials to reduce biofouling but notes that manual cleaning will be required.
93	Evaluation of Juvenile Fish Bypass and Adult Fish Passage Facilities at Water Diversions in the Umatilla River	Knapp, Suzanne M.	1993	RKG	Evaluation of the juvenile fish bypass and adult passage facilities for the projects in the Lower Umatilla River.
150	Field Evaluation of Passive Bar Screens for Guiding Juvenile Salmonids Out of Turbine Intakes of Hydroelectric Dams	Krcma, Richard F., Winston E. Farr and Clifford W. Long	Unknown	RKG	Discusses the implementation of bar screens in turbine intakes to replace submersible traveling screens.
167	Modular Fish Screen Hydraulic Model Study	Kubitschek, Joseph	1995	PLJ	A hydraulic model study is used to develop porosity control or internal vanes to generate uniform through screen velocity distributions for a fixed horizontal screen module. The vanes, which modified the internal sink characteristics, were found to be both awkward and ineffective. Use of a variable porosity, perforated plate yielded effective porosity and velocity distribution control. The modular screen requires additional development (cleaning system, installation details, biological effectiveness evaluation) prior to general application.
116	Phone Memo/Trip Report of USACE/PUD Smolt Bypass Workshop	Kurkjian, Donald/SWEC	April 1994	RKG	Overview of smolt bypass workshop which focused on surface collection and fish guidance efficiency.
68	Tools for Maximizing Hydropower Generation while Minimizing Water Use	Liddell, Vincent J.	1995	RKG	Not Relevant. Discussion on using existing plant efficiency and flow data as a basis for optimizing water consumption and power output of the facility.
72	Debris Removal from a Low-Velocity, Inclined Fish Screen	Locher, F.A., P.J. Ryan, V.C. Bird, and P. Steiner	1993c	RKG	Re-write of Doc. No. 47, same information presented.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
40	Controlling Fish Movement with Sonic Devices	Mussalli, Y.G., R.S. McKinley, and P.H. Patrick/SWEC	1988a	RKG	Not relevant. Tests using a fishdrone (sonic vibrations), speaker system and hammer (spring mass impact device) indicated that the use of acoustic stimuli either to attract or repel fish is generally ineffective.
37	High Performance Traveling Water Screen for Millstone - Unit 3 Water Intake	Mussalli, Y.G., M. McNamara, and R. Cheesman/SWEC	1993a	RKG	Traveling water screen supplied with fiberglass buckets for seaweed control at 350 cfs service water intake.
39	Development of High Performance Traveling Water Screen for Millstone - Unit 3 Water Intake	Mussalli, Y.G., M. McNamara, and R. Cheesman/SWEC	1993c	RKG	Re-write of as Doc. No. 37, same information.
64	Experimental Fish Guidance Devices	National Marine Fisheries Service	1995b	RKG	NMFS believes that positive-exclusion barrier screens are appropriate for utilization in the protection of downstream migrant salmon at all intakes.
59	Revised Juvenile Fish Screening Criteria	National Marine Fisheries Service	1995a	SRT	**Document summarized in Summary No. 13.**
122	A Guidance Manual for the Input of Biological Information to Water Intake Structure Design	Neitzel, D.A., M.A. Simmons, and D.H. McKenzie	December 1981	PLJ	Guide to consideration of biological, hydraulic, water quality, and habitat influence in selection of intake designs and locations. Document is conceptual and thus offers no direct application direction.
123	Procedure for Developing Biological Input for the Design, Location or Modification of Water Intake Structures	Neitzel, D.A. and D.H. McKenzie	December 1981	PLJ	Expansion on the previous document. Gives examples and insight into application. Although oriented at organism exclusion it is equally applicable to increasing collection/passage efficiency. Although still conceptual, gives considerable insight into intake design and siting. Cites numerous references on site and species specific influences on entrainment.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
88	Evaluation of Juvenile Fish Bypass and Adult Fish Passage Facilities at Three Mile Falls Dam, Umatilla River	Nigro, Anthony A.	1989	RKG	Evaluation of the juvenile bypass facilities (drum screens) and the adult passage facilities at Three Mile Falls Dam, Umatilla River.
82	New $7.4 Million Fish Bypass System Being Installed at Wanapum Dam	Northwest Public Power Association (NWPPA) Bulletin (unauthored)	1995	SRT	Article on the Wanapum fish bypass system prototype recently installed.
127	A Fish Protection Facility for the Proposed Peripheral Canal	Odenweller, Dan and Randall Brown	April 1981	PLJ	Summary of document number 168.
168	Delta Fish Facilities Program Report Through June 30, 1982	Odenweller, Dan B. and Randall L. Brown	1982	PLJ	Summarizes field and laboratory work conducted by the State of California in developing a fish exclusion system for the proposed Peripheral Canal. Proposes a positive barrier screen using 2.4 mm slot width wedge-wire. Concludes that 6.1 cm/s is an appropriate design approach velocity for fry and juvenile American shad and chinook salmon. Proposes selective curtailment of diversion for larval fish exclusion. Studies evaluate cleaning, corrosion, clogging, swimming performance, and screen opening size selection.
44	Hydraulic Modelling of Fish Screens	Odgaard, A.J., Y. Wang, M. Serre and R.A. Elder	1993	RKG	The effort underway at Iowa Institute of Hydraulic Resistance (University of Iowa) is an attempt to create a data bank of pressure-loss coefficients for typical screen configurations.
54	Arbuckle Mountain Hydro Vertical-Axis Fish Screens	Ott, R.F., J.J. Strong and H.E. Finch	1987b	RKG	Cylindrical-type wedge-wire screens used for small flows.
52	Innovative Intake Protects Both Aquatic Life and Turbine Equipment	Ott, R.F., E. Boersma and J.J. Strong	1987a	RKG	Dewatering system used concave screens (Coanda-type). Application has been for small hydro projects (<3 MW) and small flows (<120 cfs).
11	Air-Burst Fish Screen Cleaning System for the Twin Falls Hydroelectric Project	Ott, Ronald F. and Donald P. Jarrett	1991	RKG	**Document summarized in Summary No. 5.**

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
152	Fish Impingement Studies at the Hanford Generating Project (HGP) December 1975 through April 1976	Page, T.L., R.H. Gray and D.A. Neitzel	August 1976	RKG	This report covers HGP's efforts to modify traveling screens with buckets and a backwash system to prevent impinged juvenile fish from being killed.
91	Transportation as a Means of Increasing Wild Juvenile Salmon Survival: Technical Report 4 of 11	Park, D.L.	1993	RKG	Report supporting the need for transporting juvenile salmon.
144	Some Design Considerations for Approach Velocities at Juvenile Salmonid Screening Facilities	Parka, Robert O. and Randall T. Lee	1991	RKG	**Document summarized in Summary No. 17.**
148	Biological Basis of Protecting Fish from Entry Into Water Intake Structures	Pavlov, D.S. and A.M. Pakhorukov	May 1974	PLJ	Review of Russian and western fish behavior and screening activities. Document includes discussion of fish behavior, swimming characteristics, intake placement, screening concepts, and behavioral fish exclusion techniques. The biological data is extensive. Unique screening concepts addressed include conical pressure screens (similar to Eicher and MIS) that use screen rotation for cleaning and a well concept that uses avoidance of sounding for fish exclusion.
125	Development of Biological Criteria for Siting and Operation of Juvenile Fish Bypass Systems: Implications for Protecting Juvenile Salmonids from Predation	Poe, Thomas P., Matthew G. Mesa, Rip S. Shively, and Rock D. Peters	September 1993	PLJ	Addresses predation as a function of bypass out-fall location. Notes that predation can negate positive benefits of the bypass. Implies that eddy free dewatering systems operating with internal velocities of 100 to 130 cm/s will minimize resident squawfish predation.
85	Fishways - An Assessment of Their Development and Design	Powers, P.D., J.F. Orsborn, T.W. Bumstead, S. Klinger-Kingsley, W.C. Mih	1985	RKG	Detailed fishway engineering and design information for upstream migrant fish.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
151	Considerations in the Design of Juvenile Bypass Systems	Rainey, William S.	May 1985	RKG	This paper emphasizes the importance of the bypass system in protecting juvenile fish at screen facilities. Screen/bypass layouts, juvenile behavior, and hydraulic considerations are addresses, followed by a discussion of key elements of the bypass design.
134	Passage of Juvenile Chinook Salmon, Oncorhynchus Tshawtscha, and American Shad, Alosa Sapidissima, Through Various Trashrack Bar Spacings	Reading, Harvey H.	October 1982	PLJ	Evaluation of day and night passage of juvenile chinook salmon and American shad through trashracks. 35 to 75 mm chinook passage appeared largely independent of bar spacing (7.6 to 30.5 cm) and dependent on velocities with passage rates declining with a velocity of 30.5 cm/s.
112A	Design Criteria/Considerations/Questions for Surface Bypass and Collection System Prototype at Lower Granite Dam	Reese, Lynn (USACE - Walla District)	March 1995a	RKG	Design criteria / considerations for Lower Granite's surface bypass and collection facility.
107C	Copy of U.S. Corps of Engineers (Walla Walla District) Juvenile Fishway Design Criteria for Lower Monumental Dam Permanent Fish Facilities	Reese, Lynn (USACE Walla Walla)	1989	SRT	Contains design criteria used by COE for Lower Monumental Dam juvenile fish passage facilities.
112D	Notes of Dewatering System Concepts for Lower Granite Dam Surface Bypass and Collection System Prototype	Reese, Lynn (USACE - Walla Walla District)	April 1995b	RKG	Presents three concepts for location of surface collector; 1) located in front of Units 4-6, 2) located in front of Units 1-3, 3) covering full width of powerhouse. All options consider release of excess water by gravity, pump-back or route through turbine.
79	Improved Cylindrical Pipe Intakes	Richards, R.T.	1979	RKG	Not relevant. Discussion of the history of development of the cylindrical pipe intake which was normally used for small flows in cooling water intakes.
107A	Notes from Discussions of Bypass Systems and Guidance Equipment - Rocky Reach Hydroelectric Project	Rickman, Eldon (PUD No.1 of Chelan County)	1992	SRT	Documents meeting discussions between Mr. Rickman and Mr. Bob Parka of NMFS regarding orifice hydraulic and cleaning criteria, trashrack proximity recommendations, bypass conduit criteria, and dewatering screen criteria for design of juvenile fish bypass system.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
58	Effects of Hydropower Development on Columbia River Salmonids	Rondorf, D.W., G.A. Gray and W.R. Nelson	1983	RKG	This paper deals with the biological concerns of fishery management on the Columbia River system.
46	Grizzly Powerhouse's Environmental Intake	Rothfuss, B.D. and W. E. Zemke	1993	RKG	Fish screen by Bixby-Zimmer (BeeZee), SS bars taper from 3/16" wide (upstream) to 1/8" wide (downstream). The 5 degree taper prevents debris from binding between bars. Trashrack is a 60-foot long double boom with a teflon scraper.
83	The Use of Floating Louvers for Guiding Atlantic Salmon Smolts from Hydroelectric Turbine Intakes	Ruggles, C.P., D.A. Robinson and R.J. Stira	~1991	RKG	Deals with the use of louvers to guide fish.
159	Downstream Migration Facilities and Turbine Mortality Evaluation, Atlantic Salmon Smolts at Malay Falls, Nova Scotia	Semple, J.R.	October 1979	RKG	Fish passage studies were conducted at Malay Falls Hydroelectric Dam, on East River, Sheet Harbour, Nova Scotia. Test fish were hatchery-reared Atlantic salmon smolt with a fork length equal to or greater than 15 cm. Turbine mortality, downstream passage rate and efficiency of a surface bypass were evaluated. Turbine mortality averaged 10.6±2.3% and was reduced to 5.1 to 5.7% of the total emigrant smolt by operation of a surface bypass without a forebay fish deflector.
158	Experiments Related to Directing Atlantic Salmon Smolts (Salmo salar) Around Hydroelectric Turbines	Semple, J. Richard and Curtis L. McLeod	September 1976	RKG	Discussion on testing of turbine intake screening done at a hydroelectric dam on the Tusket River, Nova Scotia in 1976. It was concluded that smolt guidance efficiency is positively dependent on deeper screening depths and reduced angle of deflection. The most efficient deflector array for smolt guidance of those tested was one in which the screens were operated at a depth of 2.44 m without a sounding lip and at an angle of 45° to the flow.
74	Zebra Mussels in North America: Impact on Hydroelectric Projects	Shephard, Burt K. and Gary M. Hoornaert	1993	RKG	Deals with the control of Zebra Mussels at hydroelectric projects.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
124	Evaluation of Models for Developing Biological Input for the Design and Location of Water Intake Structures	Simmons, M.A. and D.H. McKenzie	December 1981	PLJ	Follow up to documents 122 and 123. Presents decision making structure that guides assessment of multiple stimulus/response relationships in intake design and selection.
92	Juvenile Passage Program: A Plan for Estimating Smolt Travel Time and Survival in the Snake and Columbia Rivers	Skalski, John R. and Albert Giorgi	1993	RKG	This report presents a plan for developing a program to evaluate juvenile salmon passage at the Lower Snake and Mid- and Lower Columbia River Projects. The plan focuses on the use of PIT- tag technology.
157	Bypass and Collection System for Protection of Juvenile Salmon and Trout at Little Goose Dam	Smith, Jim Ross and Winston E. Farr	February 1975	RKG	Describes the physical characteristics, operation and effectiveness of the fish passage facilities at Little Goose Dam as of 1975.
60	Clogging, Cleaning, and Corrosion Study of Possible Fish Screens for the Proposed Peripheral Canal	Smith, Lawrence W. (California Department of Water Resources)	1982	RKG	**Document summarized in Summary No. 16.**
9	Cleaning and Clogging Tests of Passive Screens in the Sacramento River, California	Smith, Lawrence W. and David A. Ferguson	1978 (est.)	RKG	Detailed analysis of debris types and loads based on time of year for the Sacramento River in California. Comparing screens of similar fish screening efficiency, perforated plate clogged faster then wire mesh which clogged faster than wedge-wire. Preliminary data from cleaning tests indicate all screens can be easily cleaned with water jet spray or a wiper brush.
71	Two Promising Technologies for Fish Protection at Hydroelectric Projects	Solonsky, Allan C.	1993	RKG	General biological discussion on benefits of high-velocity screening and surface collection.
67	Using Conventional Fish Screens at Hydroelectric Projects	Solonsky, Allan	1995	RKG	Fashioned in a Question and Answer type format, this article gives general answers to typical questions pertaining to fish screens.
10	Headloss Characteristics of Six Profile-Wire Screen Panels	Stefan, Heinz and Alec Fu	1978	RKG	Headloss coefficients for various screens at various orientations.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
45	Long Term Hydroacoustic Evaluations of a Fixed In-Turbine Fish Diversion Screen at Rocky Reach Dam on the Columbia River, Washington	Steig, T.W. and B.H. Ransom	1993	RKG	Not relevant.
133	Innovative Fish Barrier for Waterfowl Lake Restoration	Strong, James	1989	PLJ	Review of screening options for larval fish exclusion. General discussion of development of a Coanda effect screen.
20	DRAFT REPORT: Surface Flow Attraction Alternative - Wanapum Development, Juvenile Fish Bypass System, Priest Rapids Project	Sverdrup Corporation	1993	RKG	**Document summarized in Summary No. 6.**
21A	Wanapum Attraction Flow Prototype Brochure	Sverdrup Corporation	1994b	SRT	Summary of prototype design features with color isometric views of the facility and color photos during construction.
21	Wanapum Attraction Flow Prototype - Bid Drawings and Specifications	Sverdrup Corporation	1994a	RVD	**Document summarized in Summary No. 7.** (INCOMPLETE)
94	Preliminary "Post-Prototype" Conceptual Designs for the Wanapum Dam Surface Bypass and Collection System	Sverdrup Corporation	1995	RVD	**Document summarized in Summary No. 14**
109	Fingerling Bypass System Study - Rocky Reach Hydroelectric Project	SWEC	1990	RKG	Design information for incorporating a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rocky Reach.
110	Conceptual Drawings for Fish Bypass and Dewatering System - Rock Island Hydroelectric Project	SWEC	1994	RKG	Design information for incorporating a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rock Island.
108	Final Study Report - Downstream Migrant Fish Bypass System - Rocky Reach Hydroelectric Project	SWEC	1992	SRT	Final report presenting two alternative arrangements of the fingerling bypass system at Rocky Reach Dam. Dewatering proposed using low velocity floor screens for both alternatives.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
111	First Powerhouse Fish Guidance and Bypass Equipment Preliminary Cost Estimate - Rock Island Hydroelectric Project	SWEC	1989	RKG	Preliminary cost estimate for a gatewell orifice type juvenile bypass collection facility, similar to the Corps projects on the Lower Snake River, at Rock Island.
33	Preventing Fish Mortality at Hydropower Facilities	Taft, Edward P. III, Elaine Bazarian, and Thomas C. Cook/SWEC	1983a	RKG	General paper summarizing the three categories of fish protection devices: behavioral barriers, fish collection systems and diversion/deterrent devices.
13	Fish Protection at Hydro Plants: Assessment of New and Old Technologies	Taft, E.P./SWEC	1986	RKG	General discussion on Behavioral barriers, Physical barriers, Collection systems and Diversion systems.
32	Preventing Fish Mortality at a Large Pumped Storage Plant	Taft, Edward P., B.N. Mochrie, T. Wright, and M. Bronoski/SWEC	1985	RKG	Describes five schemes for protecting fish from passing through the turbine when operating in the pumping mode. The schemes selected were: angled bar screens, angled fish louvers, bar racks in the existing trash rack slots, bar racks on the face of the powerhouse and bar racks across the tailrace.
14	Studies of Fish Protection Methods at Hydroelectric Plants	Taft, E.P., J.K. Downing, and C.W. Sullivan/SWEC	1987a	RKG	Summary paper regarding selection of sites (Hadley Falls/Holyoke, Ludington Pumped Storage Facility, Wapatox Canal and Wanapum) for "Behavioral" testing of mercury lights, spill, sound and limited screening.
34	State-of-the-Art in Preventing Turbine Mortality at Hydro Facilities	Taft, Edward P. III and Elaine Bazarian/SWEC	1983b	RKG	Parent document of EPRI's 1986, "Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application", EPRI AP-4711.
135	Fish Passage at Hydroelectric Projects	Taft, Ned	August 1994	PLJ	Summary of Document Number 2.
29	Successful Behavioral Devices for Fish Protection	Taft, E.P./SWEC	1989	RKG	Not relevant. Results indicate that the response of fishes to mercury lights, strobe lights and sound devices are species- and device-dependent. Sound devices have not resulted in any significant fish response. Strobe lights either repel fish or have no effect. Mercury lights attract some species, repel others and have no discernible effect on still others.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
78	Introducing a "Modular" Approach to Fish Screen Installation	Taft, Edward P., Fred C. Winchell, Thomas C. Cook, and Charles W. Sullivan/SWEC	1992	RKG	Discussion of the development of the Modular Inclined Screen (MIS) is presented.
140	Angled Screens and Louvers for Diverting Fish at Power Plants - Journal of the Hydraulics Division ASCE	Taft, Edward P. III and Yusuf G. Mussalli/SWEC	May 1978	RKG	Discussion on the pro's and con's of louver systems as compared to angled screens. Identifies projects and studies which apply to both systems.
31	Studies of Fish Protection Methods at Hydroelectric Plants	Taft, E.P., J.K. Downing, and C.W. Sullivan/SWEC	1987b	RKG	Not relevant. Pertains only to using mercury lights to attract fish.
8	Biological Engineering Investigation of Angled Flush Fish Diversion Screens	Taft, E.P. III, and Y.G. Mussalli/SWEC	1977	RKG	Discusses the use of angled fish screens for fish protection at cooling water intakes. Screens were angled at 25° to the direction of flow with 1.0 fps approach velocity.
35	Study of Fish Protection Methods Related to a Potential Alaskan Hydropower Development	Taft, Edward P. III and John S. Isakson/SWEC	1983c	RKG	This paper discusses placing traveling screens in a Vee type configuration in a turbine intake for a proposed hydroelectric facility. Testing presented in the paper deals mainly with fish impingement on the screen and not detailing screening methods.
24	Review of Fish Entrainment and Mortality Studies	Taft, Ned, Fred Winchell, John Downing, Jack Mattice, and Charles Sullivan/SWEC	1993	RKG	Average salmonoid mortality rate for Kaplan turbines is 7.6% and for Francis turbines is 18.2%.
131	Investigations on the Protection of Fish Larvae at Water Intakes Using Fine-Mesh Screening	Tomljanovich, David A., John H. Heuer and Clyde W. Voigtlander	February 1977	PLJ	Evaluation of larval fish exclusion characteristics of woven screen. Not applicable to this study.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
154	Evaluation of Two Concepts for Protection of Fish Larvae at Cooling Water Intakes	Tomljanovich, D.A., J.H. Heuer, M. Smith, P. Smith, S. Vigander, R. Whitaker, J.B. Brellenthin, J.T. Johnson, and S.H. Magliente	May 1980	RKG	This report details laboratory investigations on the impinge-release and avoidance concepts for protection of larval fish at cooling water intakes.
112B	Lower Granite Prototype Development: Preliminary Plan for Tests in 1996	USACE - Walla Walla District	February 1995b	RKG	Preliminary plans for Lower Granite's surface collector and guidance curtain.
114B	Design Drawings for Permanent Juvenile Fish Bypass Primary Dewatering System for Lower Monumental Dam	USACE	August 1990a	RKG	System configuration drawings for the primary dewatering facility.
102	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix E - Improvements to the Existing Systems Technical Report - Draft	USACE	1994f	RKG	This reconnaissance-level study focuses on improvements to fish hatcheries, juvenile fish collection and bypass systems, juvenile fish transportation systems, adult passage systems, and modifications to the dams.
101	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix D - Upstream Collection and Conveyance Snake and Columbia Rivers Technical Report - Draft	USACE	1994c	RKG	This report examines options that might reduce juvenile salmonid losses that result from migration through the existing hydropower dams and reservoirs on the Snake and Columbia River system.
112	Pertinent Data from Water Control Manual for Lower Granite Lock and Dam	USACE	1987a	SRT	Technical data for lock and dam facilities including fish facilities.
103	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix F - System Improvements Technical Report Lower Columbia River - Draft	USACE	1994g	RKG	This report presents preliminary information on possible improvements to existing lock and dam projects on the lower Columbia River operated by the U.S. Army Corps of Engineers, Portland District.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
106	Lower Granite Lock and Dam - Surface Collector Prototype Drawings	USACE	1995a	RKG	N/A - This concept was not used.
112C	Preliminary Design Drawings for Lower Granite Dam Surface Collector Module	USACE - Walla Walla District	March 1995c	RKG	Preliminary plans for Lower Granite's modular surface collector.
114	Pertinent Data from Water Control Manual for Lower Monumental Lock and Dam	USACE	1987c	RKG	Technical (pertinent) data from "Water Control Manual for Lower Monumental Lock and Dam".
98	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix A - Lower Snake Reservoir Drawdown Technical Report - Draft	USACE	1994b	RKG	This report is a comprehensive evaluation of proposed lower Snake reservoir drawdown alternatives. It includes engineering-related issues, environmental and socioeconomic impacts, and mitigation opportunities.
113D	Design Drawings of the Permanent Juvenile Fish Facilities Phase II Primary Dewatering System at Little Goose Dam	USACE	January 1989a	RKG	System configuration drawings for the primary dewatering facility.
113C	Revised Design Drawings of the Primary Dewatering System at Little Goose Dam	USACE	August 1988c	RKG	Revised design drawings for the collection channel and primary dewaterer.
114A	Lower Monumental Juvenile Fish Bypass Water-Up Plan	USACE	Unknown b	RKG	Description of the water-up and normal operation of the collection gallery, dewatering structure, downstream flume and drain to the adult fish ladder.
99	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix B - John Day Reservoir Minimum Operating Pool Technical Report - Draft	USACE	1994c	RKG	This report presents the results of a reconnaissance study of a proposal to operate John Day at its minimum operating pool (MOP) for the benefit of migrating juvenile anadromous fish.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
100	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Appendix C - Additional Snake River Basin Storage Technical Report - Draft	USACE	1994d	RKG	This report presents the status of the Galloway Project study. The report also presents a summary of the findings from the BOR-led interagency upstream storage study.
115A	Hydraulic Design Section from McNary Dam	USACE	Unknown c	RKG	Hydraulic design criteria for the McNary juvenile fish facility.
115B	Design Drawings for Permanent Juvenile Fish Facilities Primary Dewatering At McNary Dam	USACE	November 1990b	RKG	System configuration drawings for the collection channel and primary dewaterer.
115C	Water-Up Schematic for Permanent Juvenile Fish Facilities at McNary Dam	USACE	February 1994i	RKG	Water-up schematic for the collection channel and transportation flume.
97	Columbia River Salmon Mitigation Analysis System Configuration Study, Phase I, Main Report - Draft	USACE	1994a	RKG	The System Configuration Study (SCS) is assessing various possible alternatives for improving survival of anadromous fish, both juveniles and adults, migrating through the lower Columbia and Snake River dams and reservoirs. Phase I is a reconnaissance level assessment of alternatives, which were identified in the NPPC *Strategy for Salmon*.
115	Pertinent Data from Water Control Manual for McNary Lock and Dam	USACE	1989b	RKG	Technical (pertinent) data from "Water Control Manual for McNary Lock and Dam".
113	Pertinent Data from Water Control Manual for Little Goose Lock and Dam	USACE	1988a	RKG	Technical (pertinent) data from "Water Control Manual for Little Goose Lock and Dam".
62	The Dalles Lock and Dam 1995 Prototype Testing - Initial Release Construction Drawings and Specifications	USACE - North Pacific Division, Portland District, Hydroelectric Design Center	1994	RVD	The Dalles prototype involved modificaiton of existing VBS. 1) New steel lined orifices with light tubes were added; 2) The bottom of the VBS was raised and blocked off; 3) The lifting beam was modified; 4) Turning vanes at the base of the VBS were installed; and 5) Spare VBS panels were installed.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
113A	Preliminary Hydraulic Analysis - Revised Design of the Primary Dewatering System at Little Goose Dam Permanent Juvenile Fish Facilities	USACE	September 1988b	RKG	Technical data for the existing fish bypass and collection facilities.
105	Draft - Lower Snake and Columbia Rivers Surface Bypass and Collection Systems Prototype Development Program	USACE	1994h	RKG	The purpose of this program is to develop and evaluate surface bypass and collection prototype concepts that may lead to permanent systems for improving survival of juvenile salmon migrating past Lower Snake and Columbia Rivers hydroelectric projects operated by the Corps.
112E	Excerpts from Water Control Manual for Lower Granite Lock and Dam	USACE	1987b	RKG	Detailed pertinent data for Lower Granite Lock and Dam.
113B	Letter Supplement No. 1 - Changes to Permanent Juvenile Fish Facilities for Little Goose Lock and Dam	USACE	Unknown a	RKG	Describes changes to the permanent fish passage facilities and justifications for the changes.
96	1992 Reservoir Drawdown Test, Lower Granite and Little Goose Dams	USACE: Wik, S., A. Shoudlers, L. Reese, D. Hurson, T. Miller, L. Cunningham, J. Leier, L. Mettler, P. Poolman, J. Buck, C. Wolff J. Smith	1993	RKG	A test of the reservoir drawdown concept was completed in March 1992, using Lower Granite and Little Goose Dams on the lower Snake River. The test was designed to gather information regarding the effects of lowering existing reservoirs substantially - to potentially improve survival of downstream migrating juvenile salmon, as proposed by various entities in the Pacific Northwest.
138	1982 Iowa Flume Study of Fish Guidance	Vandenberg, Raymond, Garland Kersh and Michael Bronoski (USACE Kansas City District)	June 1983	PLJ	Non-salmonid flume study of fixed screens. Resultant approach velocities of 1.0 and 2.5 ft/s were evaluated. 30° inclined screen yielded better guidance than a 20° inclined screen. Good guidance was achieved with resultant approach velocities below 1.5 ft/s. Increased impingement was observed with an approach resultant velocity of 2.5 ft/s. No performance difference between woven inclined screen, wedge-wire inclined screen, and vertical wedge-wire angled screens was noted.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
155	Fish Protection with Wedge Wire Screens at Eddystone Station	Veneziale, Edward J.	Unknown	RKG	Discusses the installation of circular wedge-wire screens replacing the traveling screens at the cooling water intake. The system included an air backflush system which eliminated fish impingement and screen fouling.
6	Current TVA Work on the Fluid Mechanics of Screens with Very Small Openings for the Exclusion of Larvae at Power Plant Cooling-Water Intakes	Vigander, Svein	Unknown	SRT	Larvae exclusion not relevant.
149	Fish Barrier Dams	Wagner, Charles H.	August 1967	RKG	Fish barrier dam were designed in the '60s due to the difficultly in maintaining fish rack barriers during heavy debris loading.
117	Wedge-Wire Kleenslot Preparation Screens - Catalog No. 105	Wedge-Wire Corporation, Wellington, Ohio	Unknown	SRT	Technical data for wedge-wire screens.
43	Fish Screen Developments Columbia River Dams	Weitkamp, D.E. and R.A. Elder	1993	RKG	Wedge-wire bar screens were determined to be preferable at Wanapum and Priest Rapids rather than the mesh used on traveling screens (in the gatewell). Vertical barrier screens in the gatewells are perforated plate with 3/16" holes (51% porosity). A second layer of perforated plate was installed on the downstream side to equalize the flow distribution.
48	An Improved Fish Sampler At Cabot Station	Whitfield, J.R., G.E. Hecker and T.D. Nguyen	1993	RKG	Not relevant. Bypass of small flows through inclined wedge-wire screens.
143	Water Velocities in Relation to Fish Behavior in the Design of Screens for Diversion of Juvenile Salmonids from Turbines at Hydroelectric Dam on the Columbia River, U.S.A.	Williams, John G./SWEC	1990	RKG	Provides design information which correlates velocity to fish behavior on submerged traveling screens currently in use at many of the Lower Snake and Columbia River Projects.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
146	Report on the Loss of Salmonid Fish at the Winchester Hydroelectric Project in 1984	Williams, Ron	June 1985	RKG	This report attempted to place a monetary value on both adult and juvenile fish lost after bypass system installation and fish ladder rehabilitation at the Winchester Hydroelectric Project.
19	Evaluation of an Eicher Fish Diversion Screen at Elwha Dam	Winchell, F.C. and C.W. Sullivan/SWEC	1993a	RKG	The concept of installing a fish screen inside of a penstock at a shallow angle to the flow was first applied by George Eicher at the T.W. Sullivan hydro plant in Oregon. This type of screen is now commonly referred to as an "Eicher Screen". Its basic principle is to sweep fish rapidly towards a bypass at high velocities, as opposed to other types of screens which are designed to maintain velocities lower than the swimming speed of the target fish species.
23	Biological Evaluation of a Modular Fish Screen	Winchell, Fred, Steve Amaral, Ned Taft, and Charles Sullivan/SWEC	1993b	RKG	**Document summarized in Summary No. 9.**
25	Research Update on the Eicher Screen at Elwha Dam	Winchell, Fred, Ned Taft, Tom Cook, and Charles Sullivan/SWEC	1993c	RKG	**Document summarized in Summary No. 10.**
142	A New Technology for Diverting Fish Past Turbines	Winchell, Fred C./SWEC	December 1990	RKG	Older version of Document No. 25.
28	Evaluation of an Eicher Fish Screen at Elwha Dam	Winchell, Fred C. and Charles W. Sullivan/SWEC	1991	RKG	Older version of Doc. No. 25 which gives some background to the development of the Eicher Screen.
141	EPRI's Evaluation of the Elwha Dam Eicher Screen and Subsequent Design Changes and Hydraulic Tests	Winchell, Fred, Ned Taft, Tom Cook, and Charles Sullivan/SWEC	September 1993	RKG	See Document No. 19. Same information given.

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Doc. No.	Document Title	Author	Publication Date	Reviewer	Comments
87	Little Naches River Passage Project	Woods, Dianna and Kent N. Russell	1990	RKG	This report documents the monitoring and maintenance work for the Little Naches River Passage Project. The projects goal was to provide salmonid access to an additional 24 miles of stream habitat in the Little Naches River and its tributaries.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Document Summaries

Summary No.	Doc. No.	Document Title, Author/Document No. and Publication Date
1	1	"Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application", EPRI AP-4711, September 1986.
2	2	"Research Update on Fish Protection Technologies for Water Intakes", EPRI TR-104122, May 1994.
3	3	"Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application", EPRI TR-104120, May 1994.
4	4	"Biological Evaluation of a Modular Inclined Screen for Protecting Fish at Water Intakes", EPRI TR-104121, May 1994.
5	11	"Air-Burst Fish Screen Cleaning System for the Twin Falls Hydroelectric Project", Ott, R.F. and D.P. Jarrett, 1991.
6	20	DRAFT REPORT: Surface Flow Attraction Alternative - Wanapum Development, Juvenile Fish Bypass System, Priest Rapids Project, Sverdrup Corporation, 1993.
7	21	Wanapum Attraction Flow Prototype - Bid Drawings and Specification, Sverdrup Corporation, 1994.
8	22	"Hydraulics of a New Modular Fish Screen", Cook, T.C., E.P. Taft, G.E. Hecker and C.W. Sullivan, Waterpower '93.
9	23	"Biological Evaluation of a Modular Fish Screen", Winchell, F., S. Amaral, E.P. Taft and C.W. Sullivan, Waterpower '93.
10	25	"Research Update on the Eicher Screen at Elwha Dam", Winchell, F., N. Taft, T. Cook and C. Sullivan, 1993.
11	36	"Design of Fishways and Other Fish Facilities", Clay, C.H., ISBN 1-56670-111-2, 1995.
12	47	"Debris Removal From a Low-Velocity, Inclined Fish Screen", Locher, F.A., P.J. Ryan, V.C. Bird and P. Steiner. Waterpower '93.
13	59	"Revised Juvenile Fish Screening Criteria", National Marine Fisheries Service (NMFS) - Northwest Region, 1995.

Document Summaries Continued

Summary No.	Doc. No.	Document Title, Author/Document No. and Publication Date
14	94	Wanapum Attraction Flow Fish Bypass System, Sverdrup Corporation, April 1995.
15	121	"Fish Diversion Techniques for Hydroelectric Turbine Intakes", Canadian Electric Association 149 G 339, 1984.
16	60	"Clogging, Cleaning, and Corrosion Study of Possible Fish Screens for the Proposed Peripheral Canal" Smith, Lawrence W. September 1982
17	144	"Some Design Considerations for Approach Velocities at Juvenile Salmonid Screening Facilities", Pearce, R.O. and R.T. Lee, American Fisheries Society Symposium 10:237-248, 1991.
18	153	"Hydraulic Model Evaluation of the Eicher Passive Pressure Screen Fish Bypass System", EPRI AP-5492, October 1987.

Document Importance Level

A level of importance was assign to each "document reference" as a summary document was reviewed to identify other books, papers or articles which may contain information relating to dewatering. Based on reference titles and text in the summary document, references were labeled as "A" if they appeared to be important for design concepts or ideas. Level "A" documents are "must have" references. Document references were labeled "B" if they appeared to have a moderate level of dewatering discussion but may not attribute to the conceptual design ideas or were "too general" in nature. Document references were labeled "C" if they appeared to have little dewatering importance. Level "C" documents were still identified since they could be important for future research and development of bypass facilities.

After review of some level "A" documents it was found that they contained little information. In the final Document Reference List for each summary some documents may have titles which sound pertinent, but after review their importance levels were reduced to "B" or "C".

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 1

Document No. 1

Reference/Title: **Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application**

Author/Document No.: **EPRI AP-4711**

Publication Date: **September 1986**

Document Contents:

Objectives: To evaluate the effectiveness of existing protection systems in minimizing the effects of hydroelectric projects on downstream fish migration.

To identify important biologic and engineering criteria proposed for fish protection systems and to ascertain the extent to which these criteria limit the applicability of existing and proposed systems.

To identify the R&D and testing needed to improve the effectiveness, to reduce costs and to determine the applicability of concepts not yet fully evaluated.

Results: Fish protection systems fall into four categories: behavioral barriers, physical barriers, collection systems and diversion systems. In the past, behavioral barriers, such as lights, sound and air bubble curtains, have not offered much promise of meeting agency goals; recent studies indicate that new designs may be more effective. Physical barriers and collection systems are seldom used. Angled screens and louvers are the most commonly used diversion systems.

The project team recommended a number of systems for further investigation: bar racks, fixed screens, louver-light hybrids, other bypass system-light hybrids and spilling-light hybrids. These recommendations resulted from an effort to move in the direction of a zero-loss goal that some agencies are imposing. Although this goal is probably not achievable, several systems developed in the past decade may come close when improvements in design and operation are made.

Dewatering Findings

The fish diversion systems described and evaluated in this document for further R&D include: Angled Drum Screens, Angled Stationary Screens, Inclined Pressure Screens, Submerged Traveling Screens (STS) and Gatewell Systems.

Krcma, Farr and Long (1979) evaluated debris removal methods for bar screens (wedge-wire) for use at hydroelectric facilities. Backflushing appeared to be the most effective method for removal of debris. A reversal of water flow through the screen for 10 seconds was sufficient to remove virtually all of the debris. Backflushing interval depends on the rate of accumulation of debris. However, it was estimated that during the months of July and August at McNary Dam on the mainstem of the Columbia River, a very conservative backflush rate would be once every 24 hours. [p. 4-75]

McGroddy, Petrich and Larson (1981) evaluated fouling and clogging of fine-mesh cylindrical wedge-wire for use at offshore intakes in marine environments. The biofouling study was conducted at the Redondo Beach Generating Station in California. Results indicate that biofouling growth will accumulate on screens placed in either shallow or offshore marine waters and contribute to hydraulic losses. Therefore, based on the identified need for frequent cleaning and the lack of a reliable system to accomplish the cleaning in an offshore installation, the retrofit of fine-mesh 0.04-0.08 in. (1-2mm) cylindrical screens on offshore marine intakes was not recommended. [pp. 4-77 to 4-78]

A barrier net has been used in the forebay of Brownlee Dam on the Snake River in Idaho. It consisted of a web of plastic sheeting that extended over 2,000 feet from shore to shore and was 120 feet deep. The net was supported by a floating boom that contained three V-shaped traps for the collection of fish. Use of the barrier net was abandoned due to the rapid deterioration of the plastic sheeting, resulting from wave action (Eicher, 1985). [p. 4-83]

One study at the Hanford Generating Plant on the Columbia River showed 95 percent survival of chinook salmon fry (40-50mm) 96 hours after collection from a continuously traveling screen modified specifically for fish protection with lifting buckets and low pressure sprays (Page, Gray and Neitzel, 1976). [pp. 4-93 to 4-94]

At the North Fork Project on the Clackamas River in Oregon, angled, vertical traveling screens are installed at two locations along a 1.9 mile long fish ladder (Gunsolus and Eicher, 1970). Downstream migrants , primarily chinook and coho salmon, steelhead trout, resident trout and whitefish, can enter the fish ladder at the North Fork Dam via a downstream migrant channel. From this point they can pass either through an open port in a gate system or can travel farther downstream where they are diverted by a set of angled screens and bypassed to the fish ladder. The screens are oriented at a 22° angle to the flow. Gunsolus and Eicher (1970) found 100 percent survival for the fish using the bypass into which the screens feed. The system is less effective for chinook smolts which tend to migrate at deeper depths and therefore are not as greatly attracted to the near-surface downstream migrant channel as are the other species. [pp. 4-120 to 4-122]

Fish diversion studies were carried out in 1983 and 1985 on the Newhalen River near Iliamna, Alaska, as part of a hydropower development feasibility study (Taft and Isakson, 1983). Studies were conducted in a 4 x 4 x 4 ft test flume using sockeye salmon outmigrants and smolts. Fish diversion tests

were carried out using a 0.04 in. (1 mm) mesh angled screen set at 25° to the approach flow. [p. 4-128]

At the Tusket River, Nova Scotia hydroelectric dam, a fish bypass was constructed through the powerhouse and a vacant draft tube opening to allow downstream migrants to avoid the turbines (Semple and McLeod, 1976). In order to guide downstream migrants away from the intakes and into the bypass, an experimental, floating-screen deflector was extended upstream from the powerhouse forebay wall. [p. 4-130]

Laboratory and large scale studies of rotating conical screens with fixed cleaning spray and internal bypasses have shown high fish diversion efficiencies (Pavlov and Pakhorukov, 1974). [pp. 4-133 to 4-134]

Rotary drum screens have been used extensively at water diversions to block the passage of fish into the diversion such that they can continue their downstream passage. (Easterbrooks, 1984) [pp. 4-140 to 4-145]

At Portland General Electric's (PGE) Pelton Hydroelectric Project, downstream migrants were successfully bypassed around the turbines via an inclined screen or "skimmer" which concentrates the fish into a relatively small volume for transport the the tailwater. The use of the skimmer was discontinued in the early 1970's when the construction of the Round Butte Hydroelectric Facility prevented further upstream migration to the Pelton Project (Eicher, 1958). [p. 4-146]

A similar concept is employed at PGE's T.W. Sullivan Hydroelectric Plant at Willamette Falls (Eicher, 1982). At this plant, downstream migrants are diverted past 12 of the 13 turbines via a louver array and subsequently enter the Unit No. 13 penstock. In this 21-ft long by 11-ft wide diameter penstock, an inclined screen was placed at an angle of 19° to the flow. The screen is of the wedge-wire design with 0.08 in. (2mm) bars with 0.08 in. (2mm) clear spacing. Because of the semi-buoyant nature of the incoming debris, the smooth surface of the screen, the high ratio of bypass to screen approach velocity (5:1.5) and the shallow angle of inclination, the screen has proven to be largely self-cleaning. Salmonids show 98 percent screening efficiency and better than 90 percent survival through the bypass. (Cramer, 1982: Miller, 1984) [pp. 4-146 to 4-149]

The Winchester Dam located on the North Umpqua River, Oregon, uses an incline screen fish collection/bypass system located in each of 2 intake bays to prevent fish from passing through the turbines. The screen series in each intake consist of main and transition screens. The main screens pivot, sloping from the intake bay bottom at the upstream end upward to the transition screens. The transition screens neck down at the downstream end of the bay and concentrate fish in front of the bypass pipe (Wagner, 1984). [pp. 4-149 to 4-152]

Interim information is available on tests conducted at the University of Washington Hydraulics Laboratory using model inclined plane screens. No descaling occurred in tests using coho and steelhead fingerlings or small (90-day type) and large (yearlings) fall chinook smolts. Except for size-related response differences (smallest fish passed through most rapidly), behavior of different species under varying hydraulic and structural conditions appeared identical (Eicher, 1985). [pp. 4-153 to 4-154]

Vigander (1978), Smith and Vigander (1978), Cook (1978) and Smith and Ferguson (1979) present extensive information on the hydraulic characteristics of wedge-wire (bar) screen which serves as a guideline for selecting proper mesh sizes for specific applications. As Eicher (1982) points out, given

proper orientation and velocity, the screens are largely self-cleaning. [pp. 4-154 to 4-155]

The submerged traveling screen (STS) has been studied extensively at a number of hydroelectric facilities on the Columbia River and its tributaries. Since 1975, the NMFS has been conducting studies on these screens for the U.S. Army Corps of Engineers (COE) for use at Bonneville Dam, McNary Dam and other COE dams on the mainstem of the Columbia and Snake Rivers (Farr, 1974: Krcma, Farr & Long, 1979: Long & Krcma, 1969). [pp. 4-155 to 4-1162]

Model and prototype studies and application of louver systems have shown, in many cases, greater than 85 percent guidance efficiency under many different experimental conditions with a variety of fish species (Taft & Mussalli, 1978). [pp. 4-164 to 4-189]

A bypass system using a horn design with pumped attraction water has been used at Green Peter Dam on the Middle Fork Santiam River since 1967. Species of concern are limited to winter steelhead smolts. The period of facility operation is requested by the Oregon Department of Fish and Wildlife and reflects smolt movements. During this time the facility is operated around the clock. Most fish appear to move at night. [p. 4-189]

This reference has been updated by:

- EPRI TR-104122, "Research Update on Fish Protection Technologies for Water Intakes", May 1994.

Document Reference List

Importance Level: A = High B = Moderate C = Low

Double letters (i.e. AA) indicate documents already obtained.

Importance	Document Author and Title
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U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 2

Document No. 2

Reference/Title: **Research Update on Fish Protection Technologies for Water Intakes**
Author/Document No.: **EPRI TR-104122**
Publication Date: **May 1994**

Document Contents:

	Section 1	Introduction
	Section 2	Behavioral Devices
	Section 3	Physical Barriers
	Section 4	Fish Collection Systems
	Section 5	Fish Diversion Devices
	Section 6	Discussion and Conclusions
	Section 7	Listing of Reviews, Proceedings and Compendia

Objectives: To comprehensively review the research advances in fish protection technologies since EPRI's 1986 technology status report (EM-4711).

Results: The most significant advances have been made in the development of high-velocity fish screens and the application of strobe lights and transducer-generated sounds for repelling fish. Successful results obtained in several studies indicate that these technologies are evolving toward use in full-scale, permanent applications.

Dewatering Findings

Fish diversion systems include various designs of pivoting, fixed or traveling screens, louvers and other types of bypasses associated with traditional or angled bar racks. Various fishery management agencies have developed velocity criteria for fish screens which can be used as a guideline in designing fish diversion systems. Care should be taken when using these criteria, since final criteria are generally set and approved by the agencies on a site-by-site basis. [p. 5-1]

The basis for screening criteria established by the National Marine Fisheries Service (NMFS) and factors to be considered in the design of angled screening facilities and bypasses are discussed in two recent papers: Rainey (1985) and Pearce and Lee (1991). [p. 5-1]

Comprehensive information relating to the design of high-velocity screens (Inclined Pivoting Screens) is presented in an EPRI report (TR-104120, 1994). [p. 5-3]

EPRI has pursued a program to refine and evaluate the Eicher screen concept since 1984. EPRI funded a laboratory study in 1984-85 which evaluated passage success with rainbow trout and smolts of coho salmon, chinook salmon and steelhead trout at the Harris Hydraulics Laboratory, University of Washington (EPRI 1987, Wert 1988). A full scale installation of an Eicher screen was installed at the Elwha Hydroelectric Project in Washington State. [p. 5-7]

EPRI is currently conducting model studies at the Alden Research Laboratory of a Modular Inclined Screen (MIS) designed primarily for non-penstock applications (EPRI Patent pending). The studies are intended to evaluate the biological effectiveness of a standardized design that could eliminate the need for site-specific hydraulic model studies and biological evaluations. For detailed information on the design of this type of screen, refer to EPRI (TR-104120, 1994 & TR-104121, 1994). [p. 5-11]

A set of fixed inclined screens were installed at the Twin Falls Hydroelectric Project on the South Fork of the Snoqualmie River in Washington State. Severe debris management problems were experienced with the screens during initial operation. An air-burst cleaning system was installed in the summer of 1990 (Ott and Jarrett 1991). [p. 5-18]

Williams (1990) provides a general overview of the problems and trends encountered at submerged traveling screens (STS) facilities studied over the past 20 years. Test results from prototype studies conducted at McNary, Little Goose and The Dalles Dams during 1991-1993 are discussed in Turner et al. (1993). [p. 5-20]

While much of the past research regarding the effectiveness of fish bypass systems on the Columbia River has focused on improving guidance efficiency, many other factors must be considered to assess the effect of a bypass system on the total survival of all fish passing the project. These include the effect of the screen on survival of non-bypassed fish. For a more complete discussion of these factors, refer to Ferguson (1992). [p. 5-22]

A declined screen mounted in an intake canal at the Salmon River hydroelectric diversion in British Columbia is described by Bomford and Lirette (1991). The screen hinges form its upstream end, and the downstream end is held in its operating position via a ballast tank. The screen is designed to operate

passively, in a structurally fail-safe manner and without power. [p. 5-22]

Angled fixed screens have been installed by California Fish and Game at a large number of irrigation diversions in California, and this type of design is becoming more common in the Pacific Northwest. Most designs utilize perforated plate or wedge-wire screening material, with mechanically-driven brushes for debris management. The first large-scale application of an angled fixed screen design in the Pacific Northwest was installed at the Leaburg Hydroelectric Project operated by the Eugene Water and Electric Board (EWEB) on the McKenzie River in Oregon. (EWEB 1992). [p. 5-22 to 5-26]

During 1992-93, two new fixed screens were constructed in central Washington. The Naches Hydroelectric Project (Wapatox) screens (Naches River - Yakima basin) are sized for a 500 cfs diversion, and utilize vertically oriented stainless steel bar screens with 0.125-inch clearance, deployed in a single-vee configuration. Screens are cleaned of debris by trolley mounted brushes. Bypass flow is 20 to 30 cfs. The Dryden screens (Wenatchee River) are sized for a 200 cfs irrigation diversion and also uses screens with 0.125 -inch clearance and trolley mounted brushes for cleaning. Both facilities have adjustable full-length, vertically oriented louvers approximately 18 inches downstream of the screens to control porosity and achieve uniform velocity distribution at the screen faces. This design feature is now standard for fixed screens, based on the substantial bypass improvements realized from a retrofit of this feature at the Leaburg screens (This report). [pp. 5-29 to 5-31]

Angled drum screens are generally considered to offer the best available method of protecting fish at sites with high debris loads. Two recent papers (Johnson 1988; Rainey 1990) have discussed factors to be considered in the design of angled drum screen facilities. [p. 5-32]

Angled traveling screens have been studied extensively for use at steam electric station water intakes. Installation and maintenance costs have prevented extensive use of these screens at hydroelectric facilities. For more detail on angled travelling screens refer to LMS (1985;1987). [p. 5-35 to 5-37]

A louver system consists of an array of evenly spaced, vertical slats aligned across a channel at a specified angle and leading to a bypass. The Northeast Utilities Service Company has undertaken a major research effort evaluating the use of louvers for diverting juvenile and adult clupeids and Atlantic salmon smolts at the Holyoke Canal and the Hadley Falls Hydroelectric Project on the Connecticut River in Holyoke, Massachusetts. For more detail on louver systems refer to NUSCO (1990) and Harza (1992). [5-42 to 5-48]

Since the 1980s, angled bar racks combined with controlled spills at a bypass facility have become one of the most frequently prescribed fish protection systems for hydroelectric projects, particularly in the Northeastern United States. Most of the angled bar rack facilities have been installed at small projects (<1,000 cfs), and their performance in diverting fish has not been evaluated in most cases. The first evaluation of this concept was a study conducted at the Wadhams Hydroelectric Project, a small (150 cfs capacity) project located on the Bouquet River in Wadhams, New York. For more detail on angled bar racks refer to Nettles and Gloss (1987). [p. 5-51]

Document Reference List

Importance Level: A = High B = Moderate C = Low

Double letters (i.e. AA) indicate documents already obtained.

Importance	Document Author and Title
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U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 3

Document No. 3

Reference/Title:	**Fish Protection/Passage Technologies Evaluated by EPRI and Guidelines for Their Application**
Author/Document No.:	**EPRI TR-104120**
Publication Date:	**May 1994**

Document Contents:

Objectives: To summarize the results of recent fish protection studies and provide guidance for designing, installing and maintaining effective installations.

Results: Recent studies have shown that many types of fish can be protected at rates exceeding 99% using high-velocity screening systems that typically can be installed at about one-half the cost of conventional low-velocity technologies. Similarly, barrier nets can provide a high level of protection at a very low cost for some types of sites. In addition, promising results obtained in several recent studies indicate that behavioral guidance systems employing strobe lights and transducer-generated sound appear to be evolving from an R&D status toward full-scale deployment at a number of sites.

Dewatering Findings

The most common physical bypass systems currently in use at water intakes in the U.S. include angled bar racks and low-velocity screening systems. Recent research has demonstrated that high-velocity screening systems can offer a cost-effective alternative to these devices. For more detailed information see Section 3.2 and 3.3 of this report and EPRI TR-104122 (May 1994). [p. 2-6]

Angled bar racks represent a low to moderate cost option for some sites, although the civil works required at many sites may result in costs comparable to other screening alternatives. The theoretical basis of an angled bar rack is that larger fish will be physically excluded, and that smaller fish may avoid the turbulence created by the rack and guide along its length to the bypass. Based on results obtained at louver facilities, it is not likely that this system will be very effective in guiding fish smaller than about 60 to 100 mm. Additional information on the effectiveness of angled bar racks should become available in the next few years as monitoring studies required by FERC at several sites become available (This Report). [p. 2-6]

A variety of low-velocity screening systems have been installed to divert fish at water intakes. These include angled drum screens, angled panel screens, inclined screens and cylindrical screens. At present low-velocity screening systems offer the only proven means for diverting very small (< 30 to 40 mm) fish. Many studies have demonstrated that a well-designed system causes little injury or mortality to the fish that are bypassed, but few studies have conclusively demonstrated a diversion efficiency exceeding 90 to 95%. The fate of non-recovered fish has rarely been quantified. These types of facilities are typically among the most costly of the available bypass options (This Report). [p. 2-6]

The high-velocity screening systems described in detail in this document may provide a significant cost savings over low-velocity screening systems. Studies conducted to date at two full-scale applications of the Eicher Screen (for screening penstocks) and laboratory studies of the Modular Inclined Screen (MIS) (designed for any water intake) indicate equal or better effectiveness than low-velocity screening alternatives. The data indicate that both the Eicher screen and MIS options are capable of providing passage survival rates exceeding 99% at velocities up to 6 to 10 fps depending on the target species and size of fish (This Report). [p. 2-7]

Complete results of biological testing and hydraulic modeling of Modular Inclined Screens are presented in EPRI TR-104121 (1994). [p. 3-64]

A biological evaluation of the MIS was conducted in a laboratory setting at the Alden Research Laboratory, Inc. (ARL) during 1992 and 1993. Passage of test species and size groups were evaluated under both clean screen and debris conditions, and a series of tests evaluating modified bypass glows was conducted with one species. Several publications listed below and a comprehensive report (EPRI TR-104121, 1994) summarize the methods and results of the MIS biological evaluation.

Cook, Taft Hecker and Sullivan (1993), Taft, Amaral, Winchell and Sullivan (1993), Taft, Winchell and Sullivan (1992) and Winchell, Amaral, Taft and Sullivan (1993) discuss the MIS and give general descriptions and guidance for MIS applications.

Wisconsin Electric Power Company (WEPCO) has evaluated methods to reduce fish entrainment at a

number of its hydroelectric facilities. Results of the evaluation indicated that the installation of a barrier net could offer a most-effective method for preventing fish entrainment and potential mortality at the Pine Hydroelectric Project. The barrier net is approximately 260 ft in length, with the height varying from 2 ft to 35ft. The barrier net was fabricated to match the flowage bottom as closely as possible. The net was intentionally installed with the top line 12 to 18 inches below the surface to allow surface debris (leaves, pine needles, sticks) to pass freely over it. The net material was noted nylon and the mesh was 1/2 inch square (1 inch stretch). [This Report Appendix A.2]

Document Reference List

Importance Level: A = High B = Moderate C = Low

Double letters (i.e. AA) indicate documents already obtained.

Importance	Document Author and Title
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Summary No. 4

Document No. 4

Reference/Title:	**Biological Evaluation of a Modular Inclined Screen for Protecting Fish at Water Intakes**
Author/Document No.:	**EPRI TR-104121**
Publication Date:	**May 1994**

Document Contents:

Section 1	Introduction
Section 2	Hydraulic Model Development and Design
Section 3	Methods
Section 4	Results
Section 5	Discussion
Section 6	Findings and Conclusions
Section 7	References Cited
Appendix A	Hydraulics of a New Modular Fish Diversion Screen
Appendix B	MIS Diversion Data Summary Tables

Objectives: To demonstrate the biological effectiveness of a standardized, compact, modular, high-velocity fish screen design that could be applied at most water intakes with minimal adaptation.

Results: MIS is capable of protecting most species of fish at rates exceeding 99% over a wide range of approach velocities. The modular design resulted in a very uniform velocity distribution over the length of the screen without the need for baffles or changes in screen porosity.

Dewatering Findings

In 1991, the Electric Power Research Institute (EPRI)developed a new fish diversion screen concept. The new screen is known as the Modular Inclined Screen (MIS). The modular design is intended to allow application of the MIS at any type of water intake. Installation of multiple units at a specific site can provide fish protection at any flow rate.

The module consists of an entrance with trash racks, dewatering stoplog slots,an inclined wedge-sire screen set at a shallow angle (15°) to the flow and a bypass for directing diverted fish to a transport pipe. The screen is mounted on a pivot shaft so that it can be cleaned by backflushing. The module is completely enclosed and is designed to operate at water velocities ranging from 2 to 10 fps, depending on the species and life stages to be protected. The screen in a prototype would be approximately 10 feet wide by 31 feet long, and would be capable of screening up to 800 cfs at a velocity of 10 fps. Guide walls, which slope inward at an angle of 20° over the downstream third of the screen, lead to the 2 x 2 ft bypass entrance.

Laboratory studies were conducted in 1992 and 1993 at the Alden Research Laboratory, Inc. (ARL) in Holden Massachusetts. The laboratory evaluation of the MIS was designed to evaluate:

1. the design configuration which yields the best hydraulic conditions for safe fish passage, and

2. the biological effectiveness of the optimal design for diverting selected fish species to a bypass.

The biological evaluation of the MIS is the focus of this report. [1-1]

Based on a refined design developed during hydraulic model studies, the 1:3.33 scale biological test facility was constructed with a single piece of 50% porosity Hendrick profile bar screen and set at an angle of 15°. Passage success was evaluated at module approach velocities of 2, 4, 6, 8 and 10 fps.The total flow volume entering the MIS facility during the tests ranged from 15 to 80 cfs and bypass flows ranged form 0.8 to 4 cfs. [3-1]

The fish species that were evaluated were selected to represent the types of fish of greatest concern at water intakes in the United States based on a review of turbine entrainment and mortality studies that have been conducted in recent years (ERPI 1992a). Testing conducted with the Eicher Screen at Elwha Dam (EPRI 1992b) has demonstrated that inclined wedge-sire screens are highly effective in diverting smolt-sized (100 to 200 mm) salmonids, but indicated some potential for mortality and/or impingement of smaller fish (40 to 60 mm) at velocities above 6 fps. Due to the more even flow distribution of the MIS hydraulic model compared to the Eicher Screen, the MIS should have the potential for eliminating unacceptable diversion-related mortality of relatively small fish. [3-5]

Debris tests with mixed deciduous leaves were conducted with all species tested in 1993. 1993 debris tests were conducted at incremental head losses ranging from 0.05 to 0.50 feet depending on the species. [3-11]

A significant modification was made to the MIS during 1993 testing. After the first series of tests was completed with coho salmon, it was evident that fish were susceptible to impingement on the screen edges along the transition walls approaching the bypass. A review of impingement locations revealed that the majority of impingements for all species that had been tested occurred along the transition wall screen edges. In an attempt to eliminate impingements on these screen locations, a 0.5 inch wide strip of duct tape was placed along the screen edges approaching the bypass. After the modification, no impingements were observed along the screen edges during the remainder of the tests conducted. [3-12]

Additional information pertaining to design of an MIS installation is provided in "Research Update on Fish Protection Technologies for Water Intakes", EPRI TR-104122, May 1994.

Document Reference List

Importance Level: A = High B = Moderate C = Low

Importance	Document Reference No. and Title
AA	Electric Power Research Institute (EPRI). 1994. Research Update on Fish Protection Technologies for Water Intakes. Prepared by Stone & Webster Environmental Services. Electric Power Research Institute, Palo Alto, CA. EPRI TR-104122.
B	EPRI. 1992a. Fish Entrainment and Turbine Mortality Review and Guidelines. Prepared by Stone & Webster Environmental Services. Electric Power Research Institute, Palo Alto, CA. EPRI TR-101231, Project 2694-01, Final Report, September 1992.
B	EPRI. 1992b. Evaluation of the Eicher Screen at Elwha Dam, Spring 1991 Test Results. Prepared by Stone & Webster Environmental Services. Electric Power Research Institute, Palo Alto, CA. EPRI TR-101704. Project 2694-01, Final Report, December 1992.

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Summary No. 5

Document No. 11

Reference/Title:	**Air-Burst Fish Screen Cleaning System for the Twin Falls Hydroelectric Project**
Author/Document No.:	**Ott, R.F. and D.P. Jarrett**
Publication Date:	**1991**

Document Contents

Introduction: The Twin Falls Hydroelectric project is typical of many run-of-river, high head hydro projects in that its intake is located in a narrow flood and debris-prone section of a high mountain stream. The intake is also screened to exclude resident trout from entering the penstocks. The major problem is keeping the screens clean so that they will not clog and create uneven through-screen velocities. Limited screen access and susceptibility to flooding excludes many of the conventional cleaning mechanisms in that they are too expensive to install and maintain. The Twin Falls project was fitted with an air-burst cleaning system that is flood proof and cost effective to construct and maintain.

Pertinent Data: The turbine intakes consist of two identical caverns fitted with passive inclined-plane fish bypass screens. Each screen is 11 feet wide, 136 feet long and is inclined upward 4° from the upstream end. The screens are constructed of stainless steel wedge-wire panels with 1/4 inch bar spacing, and are supported from below with steel I-beams spaced on 2 foot 9 inch centers. Each screen passes flows ranging from 50 to 355 cfs. Bypass flows ranging from 20 to 38 cfs pass over a full-width weir at the downstream end of each screen into a common fish bypass channel which re-enters the river downstream of the project.

General Criteria: The model used for preliminary design was the air-burst system operating at the Arbuckle Mountain Hydroelectric project located in Northern California. Even though the Arbuckle project used vertical cylinderical screens (Ott, et. al. 1987) many of the design criteria were directly applicable to Twin Falls. These criteria and others found in the references are listed below:

- Air should be uniformly released across the section to be cleaned.
- Air-burst pressures should be capable of being varied from 80 to 125 psi.
- The volume of air released should completely fill the area between the supports below each screen section.

- The burst duration should be variable between 1 to 5 seconds.

- The burst cycle should start upstream and work downstream to the overflow weir.

- The length of time between individual bursts should be variable between 10 to 20 seconds.

- The time between complete burst cycles should be variable, usually 1 cycle per hour for clean water periods and 15 to 20 cycles per hour in high debris load periods.

- Air should not be entrained into the penstock so as to cause high dissolved gases in the river below the tailrace.

Conclusions: An air-burst cleaning system at the Twin Falls Hydro project shows a promising concept, whereby fish screens in remote, flood-prone sites can economically and effectively be cleaned. The system may be a cost-effective way to clean screens that are retrofitted on remote, confined sites where access is limited.

References:

Brown, R.T., J. Gordon and C. Bohac. 1990. "Measurement of Upwelling Flow from Air Diffuser", Journal of Environmental Engineering, Vol. 115(6).

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Summary No. 6

Document No. 20

Reference/Title:	**Draft Report - Surface Flow Attraction Alternative - Wanapum Development, Juvenile Fish Bypass System, Priest Rapids Project, Version 1.0**
Author/Document No.:	**Sverdrup Corporation**
Publication Date:	**December 3, 1993**

Document Contents

Introduction

The Grant County Public Utility District #2 (District) has been actively pursuing an effective and viable method of diverting downstream migrating salmon smolts away from the turbine intakes of their Wanapum and Priest Rapids Dams for a number of years. The current design at Wanapum consists of fixed bar submerged diversion screens similar to those being employed at other Columbia and Snake River projects. Fish Guidance Efficiency (FGE) tests have shown that the screen has not been able to consistently divert 70% of the migrating salmon away from the turbines.

The District has been investigating the use of a surface flow attraction diversion system as an alternative to turbine intake screening. The system is based on the knowledge that salmon smolts tend to be surface oriented fish and would be likely to choose an alternative to diving deep into the unit intakes if one was available to them.

USACE is currently developing a surface bypass system prototype similar to the alternative described in Option 1 (below) to be tested during the '96 season at Lower Granite Lock and Dam.

Assumptions/Considerations/Design Options

Analysis of experimental and operational surface flow attraction systems shows that the efficiency of a system in diverting juvenile salmonids away from turbine intakes depends on a number of factors. The ideal combination of these factors to produce desirable results at any given site is not clearly known and research is currently on-going. The following are some of the factors which were considered during the design of a surface flow attraction system for Wanapum Dam:

- The system should create a velocity field in the upper half of the forebay which tends to attract the fish.

- A sufficient quantity of flow needs to be used so that a fish moving downstream can sense the velocity field far enough upstream that it presents a viable, attractive, alternative to following the turbine flow.

- The entrances to the system must be as close to the turbine intakes as possible, preferably directly above them as at Wells Dam.

- To be as fish friendly as possible, the intakes should extend over the same portion of the water column that the juvenile salmon naturally occur in so as to not force the fish to change elevations to enter the system.

- Channel velocities should be high enough to keep the fish moving through the channel, but low enough so as not to cause excessive headloss.

- Since it is not yet known what the horizontal fish distribution will be with the influence of the attraction velocities imposed on the forebay, a linear distribution is assumed and system entrances are evenly spaced along the powerhouse.

At Wanapum Dam, the trash sluice and spillways are located too far from the powerhouse units to be an effective source of diversion for fish which have been attracted toward the powerhouse flow. It was proposed that a channel be constructed which extends completely across the face of the powerhouse directly above the unit intakes, similar to an ice and trash sluiceway but much deeper. On the forebay side, the channel wall contains vertical slots for allowing water to flow unimpeded from the upper portion of the forebay into the channel.

A set of preliminary design assumptions concerning total flow, individual slot flows, channel depth, channel velocities, number of slots, slot dimensions and slot spacing was developed for the purpose of creating conceptual design options. Design assumptions were as follows:

- The floor of the channel is set low enough to occupy approximately 50% of the water column.

- The slots are spaced 90 feet apart providing for one slot per turbine.

- Slot dimensions will be somewhat adjustable, however they will initially be sized for a flow of 750 cfs which represents 5% of one unit flow (15,000 cfs).

- The channel is sized based on a maximum channel velocity of 7 fps.

- The channel will contain 14 slots, one for each of the existing ten units and four additional slots for future units.

Five options were investigated for further consideration to create a surface flow attraction system at Wanapum Dam. Each of the options incorporate the basic channel and slot configuration as described above. The differences between the options concern the method of discharging the fish downstream of the dam.

Option 1 - Spillway Discharge

Option 1 consists of a steel channel in the forebay, attached to the powerhouse pier noses, extending across the existing and future units. The channel continues past Unit 16 and discharges the entire flow, including fish, through the first spillway bay beyond the existing trash sluice. The channel is 6.5 feet wide at Unit 1 and expands 1.75 feet at each slot (between each unit) to a final width of 29.25 feet. The slots are located on the transition surfaces.

Option 2 - Future Unit 11 Discharge

Option 2 is the same configuration as Option 1, but would discharge water and fish through the Future Unit 11 intake structure instead of the spillway. Discharge is controlled by bulkhead/slide gates.

Option 3 - Low Velocity Dewatering Screens

Option 3 is the same configuration as Option 1, however this option includes dewatering. Inside the channel is a full height vertical wall extending from slot 6 to the downstream end of the channel. The wall has perforated screen sections with porosity plates on the back side. Each perforated screen section is sized to pass approximately 350 cfs. Channel velocities remain at 5 to 7 fps, screen normal velocities are 0.5 fps. At the end of the channel the bypass flow remaining is approximately 350 cfs. The bypass flow enters a 6-foot diameter transportation pipe which can be routed to an appropriate location. This configuration would discharge excess water through the Future Unit 15 intake structure. Discharge through Future Unit 15 is controlled by bulkhead/slide gates.

Option 4 - High Velocity Dewatering Screens

Option 4 uses screens to remove the excess channel flow as in Option 3. However, high velocity bar screens are used in this Option. The bar screens are similar to the submerged bar screens currently in use at many of the Columbia and Snake River projects. The high velocity screens gross area is 5,100 square feet as compared to 20,400 square feet for the low velocity screens used in Option 3. Channel velocities remain at 5 to 7 fps, screen normal velocities are 2.0 fps.

Option 5 - Pump-back Attraction System

Option 5 entails using submerged pumps located behind low velocity screens to develop the necessary attraction flow through the intake slots. A major difference between this option and the other options is that there would not be a continuous channel. Each unit of the powerhouse has an individual collection box. Each box contains one adjustable slot panel with a flow of 750 cfs. As the fish travel the 90 feet from the slot at one end to the discharge at the opposite end, approximately 730 cfs passes through a low velocity full height screen wall similar to that described in Option 3.

See Document No. 21 - "Wanapum Attraction Flow Prototype - Bid Drawings and Specifications" and Summary No. 7 for the final alternative for prototype.

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Summary No. 7

Document No. 21

Reference/Title:	**Wanapum Attraction Flow Prototype**
Author/Document No.:	**Sverdrup Corporation**
Publication Date:	**9/6/94**

Background: There are two other significant documents available on the Wanapum Bypass, Document 20 (1993) and 94 (1995), which are summarized in Summary No. 7 and 14, respectively. Document 20 covers five (5) different options, of which none were used for the prototype. Document 94 covers eleven (11) different options.

Abstract: This document contains the Bid drawings for the 1995 Surface Bypass for the Wanapum Project. The approach for this season was to provide a prototype which could be designed, fabricated, and installed in the available time frame; and be flexible enough for future modification.

The structural steel modules are anchored to the face of the piers by 1 1/4" Maxibolts.

The bypass structure was designed to simulate the configuration of modules along the entire powerhouse. The upstream collection channel section has no flow through the module and fish are prevented from entering this section by an isolation wall. The entrance slot size can be varied from 8 feet to 16-feet wide during operations, but can be fully closed for unit shutdown. The overall height of the opening is 50 feet with three (3) lower doors which are 15 feet tall and one (1) upper door which is 5 feet tall. The total flow entering the structure is 1,400 cfs. The entrance is always submerged, which helps keep the floating trash from entering the structure.

After the entrance slot, the 12-foot wide collection channel continues for 90 feet. At this point, a coarse trash rack is provided with a 1-foot bar spacing. The sidewall dewatering starts approximately 70 feet downstream of the trashrack. The sidewalls converge symmetrically from 12-foot wide opening to a 5-foot wide opening. The overall length of the dewatering section is approximately 42 feet long. The first half of the floor is flat and the second half is sloped upward at approximately 45 degrees. A flow of 500 cfs enters an elongated pipe (5 ft W x 10 ft H), with a resulting velocity of about 11 fps.

The dewatering structure has eighty (80) 6.5 ft x 7.5 ft stainless steel perforated plate panels with a porosity of 51 %. The last four (4) panels, just prior to entering the elongated pipe, have a reduced porosity of 32.6%. It should be noted that in all the structures which SWEC and NPW inspected, the converging side dewatering

configuration resulted in higher normal velocities in the downstream dewatering sections. It appears that the reduced porosity addresses this situation.

The system is drafted by sixteen (16) axial flow blowers , oriented such that the flow is parallel to the upstream face of the powerhouse. The normal flow through fourteen operating blowers is 900 cfs. Two additional blowers are for back-up. The backside of each blower is covered with a flap gate to prevent backflow through the blower if it is off-line.

The elongated pipe transitions into a 7.5 ft Ø pipe which penetrates the dam. As the pipe passes through the dam, it increases to 8.0 ft Ø and enters a emergency shut-off knife gate. The pipe continues at the same elevation, exits the dam, and is routed toward the spillway on the downstream dam face. When the pipelines centerline starts to drop, the pipe diameter decreases to 7.5 ft. The pipeline is routed along the training wall between the trash sluiceway and the first spillway tainter gate. The outfall is 21 feet above high tailwater and 35 feet above low tailwater. During bypass operation, both the trash sluiceway and the first spillway tainter gates are open to provide higher velocity at the outfall.

The outfall pipeline is fully pressurized and the discharge is controlled by a modified knife gate near the downstream end. The knife gate's lower bonnet is filled by a spring loaded plate which slides up to fill the invert gate leaf slot when the gate is open. This filler provides a smooth surface and reduces the turbulence when the gate is partially open. When the pipeline is passing 500 cfs, the gate is open 31 inches. Just upstream of the control knife gate, there is a roof deflector to reduce the dead area which would occur if the gate is partially open.

The method of cleaning the sidewall dewatering screens is manual, by means of a long handled brush. The project does not feel there is enough trash at the site to justify the additional cost of a mechanical cleaning system at this time.

Conclusions: N/A

Reference: N/A

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Summary No. 8

Document No. 22

Reference/Title:	**Hydraulics of a New Modular Fish Screen**
Author/Document No.:	**Cook, T.C., E.P. Taft, G.E. Hecker and C.W. Sullivan**
Publication Date:	**Waterpower '93**

Document Contents

Abstract: To prevent fish from passing through turbines, EPRI has developed a new Modular Inclined Screen (MIS) concept. Various laboratory flow facilities have been used to test the MIS for fish screening efficiency and flow characteristics. Data from these tests show high fish screening efficiencies and favorable hydraulics for a wide range of approach velocities.

Text: The modular design provides flexibility for application at many types of intakes, particularly for those plants without penstocks, and for a range of flows by varying the number of modules. It is being designed from hydraulics and fisheries viewpoints, which has resulted in a device which limits hydraulic losses while not harming fish. This paper discusses the hydraulic testing conducted, while another paper discusses the biological test results (Winchell et. al. 1993).

One MIS consists of a streamlined entrance with a trash rack, dewatering stoplog slots, a wedge-wire screen and a bypass for diverting fish. The screen is a plane of commercially available 50% porosity wedge-wire, set at an angle of 10° to 20°. The screen is set on a pivot shaft so that it may be tilted and thus cleaned via backflushing.

Conclusions: The Modular Inclined Screen (MIS) has favorable hydraulic characteristics, and may be used in a variety of approach flow orientations and flow magnitudes conditions with consistent results. With approach velocities ranging from 2 to 10 fps, the normalized velocities along the screen face are nearly constant, and fish moving along the screen would not experience dramatic velocity changes. Finally, the head losses created with the MIS system are relatively small.

Reference: Winchell, F., S. Amaral, E.P. Taft and C.W. Sullivan. 1993. "Biological Evaluation of a Modular Fish Screen". Waterpower '93.

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Summary No. 9

Document No. 23

Reference/Title:	**Biological Evaluation of a Modular Fish Screen**
Author/Document No.:	**Winchell, F., S. Amaral, E.P. Taft and C.W. Sullivan**
Publication Date:	**Waterpower '93**

Document Contents

Abstract: The Electric Power Research Institute (EPRI) has developed and is presently testing a new type of fish diversion screen known as the Modular Inclined Screen (MIS). The screen is designed to operate at high water velocities (up to 3 m/sec) and is, therefore, significantly more compact than conventional low velocity screening systems. A biological evaluation of the MIS was conducted in 1992 with juveniles of six fish species: bluegill, walleye, rainbow trout, channel catfish and two alosid species that were tested as one group. The results of this laboratory study demonstrate that the MIS has excellent potential for providing effective fish protection at water intakes.

Text: Clean screen fish passage tests were conducted at module velocities of 0.6, 1.2, 1.8 2.4 and 3.0 m/sec. Debris tests were performed at these same velocities with the exceptions of 0.6 and 3.0 m/sec. and the addition of 0.4 m/sec. Debris tests were conducted to assess the ability of the screen to be cleaned by backflushing and to determine the effect of debris accumulation on flow conditions and fish passage. Pine needles, deciduous leaves and aquatic vegetation were used individually in three separate debris tests series.

After each test was completed the screen was examined to determine the number and location of all fish that were impinged. If possible, impingements were removed form the screen before the next test began. Diversion efficiency was calculated as the ratio of fish collected live to the total number of fish collected (i.e., live and dead fish collected from the net pen and the number of impingements combined).

Rotation of the screen for brief periods (approximately 1 minute) flushed the large majority of debris from the screen at all velocities. The head loss associated with this residual debris (above that measured for a clean screen) ranged from 0.3 cm at 0.4 m/sec to 5.5 cm at 2.4 m/sec.

Debris tests with leaves and aquatic vegetation showed that the relationship between head loss and fish impingement was similar for all debris types tested. No impingements occurred at 3.0 cm of head loss and only minor impingements (<5%) at 7.5 cm. At greater levels of head loss, impingements rates were higher for tests with leaves and aquatic vegetation than tests with pine needles.

Conclusions: The results of the biological testing clearly demonstrate that the MIS can effectively and safely diver fish to a bypass. Impingement and latent mortality is generally low, even at approach velocities as high as 3.0 m/sec. Also, it was determined that debris can be effectively removed by rotating the screen for backflushing and that minor levels of debris accumulation have little effect on fish passage. The biological effectiveness that has been demonstrated to date combined with the modular design of the screen system, supports the conclusion that the MIS is a cost-effective, viable fish protection technology.

Reference:

Cook, T.C., E.P. Taft, G.E. Hecker and C.W. Sullivan. 1993. "Hydraulics of a New Modular Fish Screen". Waterpower '93.

Electric Power Research Institute (EPRI). 1992. "Fish Entrainment and Turbine Mortality Review and Guidelines". EPRI Report No. TR-101231.

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Summary No. 10

Document No. 25

Reference/Title: Research Update on the Eicher Screen at Elwha Dam
Author/Document No.: Winchell, F., N. Taft, T. Cook and C. Sullivan
Publication Date: Waterpower '93

<u>Document Contents</u>

Introduction: The Electric Power Research Institute (EPRI) conducted two years of biological evaluations of an Eicher Screen installed in a 9-foot diameter penstock at the Elwha Hydroelectric Project in Washington State. Testing has shown passage survival to equal or exceed 98.7% for steelhead smolts, coho smolts, chinook smolts, coho fingerlings and chinook fingerlings. Scale loss injuries were minimal at velocities of 4 - 6 fps, but increased at higher velocities. Most injuries occurred from the fish contacting the screen in an area where it transitions from 63% porosity to 32% porosity wedge-wire material, where the velocity component perpendicular to the screen was relatively high.

Test Results: Test results showed that passage survival (diversion efficiency adjusted for 96-hour survival) equalled or exceeded 98.7% for all three species of smolts tested. Although the facility was not specifically designed to pass fish smaller than smolts, passage survival exceeded 95.9% for; coho fingerling pre-smolts (99.2%), chinook fingerling pre-smolts (99.9%), steelhead fry (97.1%) and coho fry (95.9%), at penstock velocities less than 7 fps. Net passage survival for the Elwha Eicher Screen is as follows:

Species/Size Class	Average Length	Adjusted Diversion Efficiency	Net 4-Day Mortality	Average Passage Survival
Steelhead smolts	144mm	99.6%	0.2%	99.4%
Coho smolts 1990	135mm	99.5%	0.1%	99.4%
Coho smolts 1991	145mm	98.7%	0.0%	98.7%
Coho juveniles	102mm	99.4%	0.2%	99.2%
Chinook smolts	99mm	99.7%	0.9%	98.8%
Chinook juveniles	73mm	99.9%	0.0%	99.9%
Steelhead fry	52mm	98.2%	1.1%	97.1%
Coho fry All data	44mm	96.1%	4.7%	91.6%
Tests < 7 fps		98.0%	2.1%	95.9%

Conclusions:

Results obtained at Elwha indicate that the Eicher Screen can divert juvenile and smolt-sized salmonids with minimal injury at penstock velocities of up to 7 fps. Descaling injuries, particularly for salmon and steelhead smolts, could result in mortality as velocities increase beyond this range. The results of the hydraulic model studies suggest that the velocity could be increased by approximately 10% if a more graduated porosity configuration were used.

The relatively limited test series conducted with fry-sized fish indicate that passage survival rates exceeding 95% can be achieved for fish in the 40 - 50 mm range at velocities up to 7 fps.

Testing conducted at different bypass flows indicate that the velocity approaching the bypass should be a minimum of 90% of the penstock velocity. Impingement could become a problem if bypass velocities are substantially lower. Bypass velocities higher than the penstock velocity did not show an appreciable effect on the test results.

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Summary No. 11

Document No. 36

Reference/Title:	**Design of Fishways and Other Fish Facilities**
Author/Document No.:	**Clay, Charles H. , ISBN 1-56670-111-2**
Publication Date:	**1995**

Contents:

Abstract: The first edition of the "Design of Fishways and Other Fish Facilities" was published in 1961. The second edition reflects the authors experience in Canada, Holland, Yukon, United States, Newfoundland, Europe, Japan and Africa. This source provides good general background and design information on fishways and adult barriers.

The chapter on "Protection for Downstream Migrants" is general in nature and documents the items of interest, methods of protection and the sites where they are employed. The chapter offers a good introduction on protection of downstream migrants, little detailed information on facility design.

Conclusions: Information provided is consistent with the design criteria imposed by the National Marine Fisheries Service (NMFS). The overview nature of the text is a good source for the "Big Picture". For design purposes, the designer should refer to other sources covered in the Literature Search.

Reference: n/a

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Summary No. 12

Document No. 47

Reference/Title:	**Debris Removal From a Low-Velocity, Inclined Fish Screen**
Author/Document No.:	**Locher, F.A., P.J. Ryan, V.C. Bird and P. Steiner**
Publication Date:	**Waterpower '93**

<u>Document Contents</u>

Abstract: An air backwash system for the Potter Valley Intake Inclining Horizontal Fish Screen Facility was developed through testing of a prototype section of the screen in a test flume located at the project site. Effects of sparger pipe spacing, sparger hole configuration, duration of the air burst and types of debris were investigated. The test program and development of the final configuration of the sparger system are described in this paper.

Conclusions: An air backwash system will satisfactorily remove debris from the Inclined Fish Screen Facility proposed for the Potter Valley Intake.

The orientation of the wedge wires had a significant effect on the design of the sparger system. Three rows of holes were required to provide the jetting action necessary to clean the screen.

Most of the debris removal takes place in the first few seconds. A three-second air burst was found to be the most effective.

An initial pressure of 100 psig or greater provided the most satisfactory cleaning action.

Successive operation of the screen panels from upstream to downstream effectively removed the debris from the screen and screen chamber.

Reference: Ott, R.F. and Jarrett, D.P., "Air-Burst Cleaning System for the Twin Falls Hydroelectric Project", Proceedings Northwest Hydroelectric Association, Portland, Oregon, Jan. 1992.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search Summary

Summary No. 13
Document No. 59

Reference/Title:	**Revised Juvenile Fish Screening Criteria**
Author/Document No.:	**National Marine Fisheries Service (NMFS) - Northwest Region**
Publication Date:	**February/March 1995**

Document Contents:

- **I.** **General Considerations**
- **II.** **General Procedural Guidelines**
- **III.** **Screen Criteria for Juvenile Salmonids**
  - **A.** **Structure Placement**
  - **B.** **Approach Velocity**
  - **C.** **Sweeping Velocity**
  - **D.** **Screen Face Material**
  - **E.** **Civil Works and Structural Features**
  - **F.** **Bypass Layout**
  - **G.** **Bypass Entrance**
  - **H.** **Bypass Conduit Design**
  - **I.** **Bypass Outfall**
  - **J.** **Operations and Maintenance**
  - **K.** **Modified Criteria for Small Screens (Diversion Flow Less Than 25 cfs)**

Objectives: Revised criteria for design of juvenile fish screening facilities including:

- Combining screen and bypass criteria into single document.
- Revised screen face material criteria.
- Metric units added.
- Small screen (<25 cfs) section added.
- Reference to "Experimental Fish Guidance Devices" position paper.

Summary of Findings:

<u>Section I: General Considerations</u>

- Guidelines apply to hydroelectric, irrigation, and other water withdrawal projects with site-specific waivers or modifications considered for extenuating circumstances.

- NMFS may require additional investigations at sites where site-specific variables are poorly defined.

<u>Section II: General Procedural Guidelines</u>

- All designs must reflect NMFS design criteria and input, be acceptable to NMFS, properly function through the full range of hydraulic conditions, and account for debris and sedimentation conditions.

Section III: Screen Criteria for Juvenile Salmonids

- **Structure Placement:**

  - In rivers, desirable for screen face parallel to river flow.
  - In rivers, desirable for screen location at intake or have return transportation facilities.
  - In reservoirs, desirable for intake location offshore with allowable approach velocities.
  - In reservoirs, screened intake diversion should provide most appropriate juvenile attraction and water temperature.

- **Approach Velocity:**

  - Limited to 0.4 fps for salmonid fry (less than 60 mm in length) assumed present at all sites.
  - Limited to 0.8 fps for salmonid fingerlings (60 mm and longer).
  - Required uniform flow distribution over the entire screen area.

- **Sweeping Velocity:**

  - Required to be greater than approach velocity.
  - Screen angle less than 45 degrees relative to flow.

- **Screen Face Material:**

  - Salmonid fry assumed present at all sites unless proven otherwise requiring the following screen material criteria:

    Maximum perforated plate openings of 3/32 or 0.0938 inches (2.38 mm).
    Maximum bar screen openings of 0.0689 inches (1.75 mm).
    Maximum woven wire screen openings of 3/32 or 0.0938 inches (2.38 mm) in the narrowest direction.

  - If salmonid fry are proven to be absence from site, the following screen material criteria may be used:

    Maximum perforated plate openings of 1/4 or 0.25 inches (6.35 mm).
    Maximum bar screen openings of 1/4 or 0.25 inches (6.35 mm).
    Maximum woven wire screen openings of 1/4 or 0.25 inches (6.35 mm) in the narrowest direction.

- **Civil Works and Structural Features:**

  - Screen surfaces shall be placed flush with adjacent screen bay, pier noses, and walls.
  - Screens shall be protected from large debris.
  - Screen surfaces shall be constructed at an angle to the incoming flow.
  - Features designed to eliminate undesirable hydraulic effects.

- **Bypass Layout:**

  - Geometry such that out-migrating juveniles pass through the system without delay and with access for cleaning.

- **Bypass Entrance:**

  - Each entrance must have independent hydraulic control, ambient lighting available, and accelerating velocity into bypass to minimize delay.

- **Bypass Conduit Design:**

  - Smooth surfaces and joints required with minimal turbulence.
  - No pumping, free-fall, negative pressure, or sharp bends are allowed.
  - Design to minimize debris clogging and sediment deposition.
  - No closure valve allowed without special approval.
  - Minimum depth of 0.75 feet and no hydraulic jump allowed.

- **Bypass Outfall:**

  - Outfall in ambient river velocities greater than 4 fps.
  - Minimize predation potential.
  - Maximum outfall velocity shall be less than 25 fps.
  - Design to avoid adult attraction.

- **Operations and Maintenance:**

  - Automatically cleaned as necessary.
  - Head differential to trigger cleaning shall be maximum of 0.1 feet.

- **Modified Criteria for Small Screens:**

  - Screens <4 feet long may be vertical.
  - Screens >4 feet long must be flatter than 45 degrees.
  - Drum screens shall be submerged 75%.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 14

Document No. 94

Reference/Title:	**Wanapum Attraction Flow Fish Bypass System**
Author/Document No.:	**Sverdrup Corporation**
Publication Date:	**April 11, 1995**

Background: There are two other significant documents available on the Wanapum Bypass, Document 20 (1993) and 21 (1994), which are summarized in Summary No. 7 and 8, respectively. Document 20 covers five (5) different options, of which none were used for the prototype. Document 21 is the Bid Drawings for the existing prototype.

Abstract: This document contains eleven (11) different options for the Wanapum Attraction Flow Fish Bypass. The approach taken for all the options are different from the prototype, they are further development of the concepts from the 1993 document.

The proposed method of cleaning is manual, by means of a long handled brush. The project does not feel there is enough trash at the site to justify a mechanical cleaning system.

Option 1 - Pumped Module

Each attraction module cover two (2) turbine units with a total of five (5) modules. The attraction flows are 1,400 cfs per module, dewatered to 60 cfs and collected into a common manifold. The resulting 300 cfs is discharged to the existing 8-foot diameter outfall.

The dewatering screens are an inclined floor screen and a converging wall screen on the downstream side. The drafting of the screens are driven by four (4) blowers per turbine inlet bay, with a total of twenty four (24) blowers per module. There is a potential of reversing the blowers for backwashing the screens through the outfall.

Option 2 - Venturi Modules

Option 2 is similar to Option 1 except the dewatering is drafted by a "venturi" opening and control gate.

Option 3 - Continuous Pumped Channel

Option 3 is similar to Option 1 except there is no collection manifold. The dewatering occurs in two steps, primary and secondary. At the start of the system 1,400 cfs is

collected at Unit 1 and dewatered to by blowers to 660 cfs. The 660 cfs passes in front of Unit 2 and 3 via a transport channel and is further dewatered. At Unit 3 an additional 1,400 cfs is added to system, is dewatered to 660 cfs, and joins the flows from Unit 1. The pattern continues for three (3) more modules with 340 cfs going to the existing outfall.

Option 4 - Continuous Gravity Channel

Option 4 is similar to Option 3 except the dewatering is drafted by the Unit 12 Bay, which is a block-out for a future unit. The flow is controlled by valves in the intake gate slot.

Option 5 - Single Unit Venturi Module

Option 5 is similar to Option 2 except there is one module per unit and the flow into each module is 700 cfs. The width of the entrance slot and the channel is one half of Option 2.

Option 6 - Two-Slot Module

Option 6 is similar to Option 1 except there are two variable inlet slots per module. The unit can be adjusted such that the mid-slot can be closed and the end slot area can be doubled in width. The inclined floor screen for the first slot is limited to a 10-foot reach in the mid-module. The bulk of the dewatering screen is located in the second half of the module.

Option 7 & 7A - Gravity Discharge

Option 7 & 7A are similar to Option 1 except the dewatering (6,700 cfs) is drafted by Unit 12 (Option 7) or the Spillway (Option 7A).

Option 8 - Three (3) Intake Trap Channel

Each attraction module covers one unit. The flow passes through a contraction zone which increases the velocity to approximately 9.0 fps. This zone acts as a velocity barrier which resist the juveniles from returning to the headwater. The dewatering is achieved in the second half of the module using wall screens drafted by the turbines. The bypass water is collected by three separate inlets at different depths, collected in a common manifold, and discharged into the existing outfall.

Option 9 - Open Channel Venturi Modules

The attraction module covers two units. The dewatering is from an inclined floor screen and a wall screen on the upstream side, and is drafted by the turbines. The bypass flow is controlled by an adjustable ogee weir which outlets in a common open bypass flume, and discharges into the existing outfall.

Option 10 & 10A - Multiple Slots with Mined or Forebay Collection Galley

The attraction module covers one bay. The dewatering is from a 45° inclined floor screen per module and is drafted by the turbines. There is one bypass inlet per unit bay (three (3) bays per unit) which is collected in a common manifold, and discharges into the existing outfall.

For this option the total attraction flow is 14,000 cfs, with a flow of 467 cfs per bay. The collection manifold is mined downstream of the trashrack (Option 10) or is mounted on the piers in the forebay (Option 10A).

Option 11 - Spillway Discharge without Dewatering

Each attraction module covers two units. The attraction flows from each module (1,400 cfs) are combined with the next module. The combined flow of 7,000 cfs is discharged through the spillway, this option has no dewatering This system is similar to that being developed by the USACE for Lower Granite Lock and Dam.

Conclusions: The eleven Options utilize several basic approaches to surface bypass and dewatering. The modules cover two units, one unit or one bay. The method of drafting the dewatering structure is a forced system with blowers into the turbine intake, a venturi system with control structures into the turbine intake, a controlled outlet into Unit 12, or through the spillway.

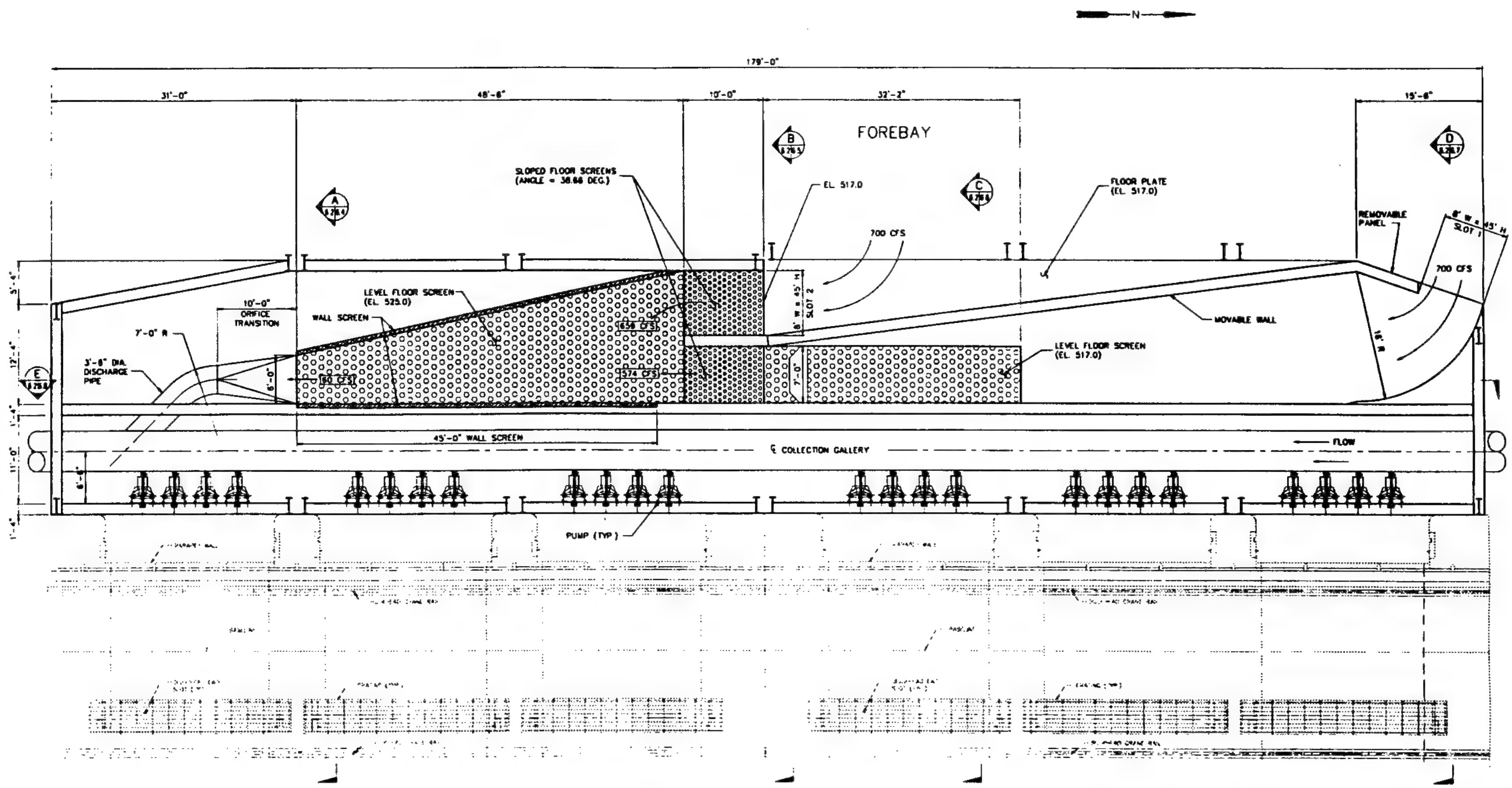
In all cases, other than Option 11, the bypass flows are routed to the existing outfall. It should be noted that the outfall is fully pressurized and is controlled by a knife gate at the discharge point. This approach deviates from the current criteria, as does Lower Granite, but was accepted by the agencies since it was demonstrated by model studies that there was no harm done to the juveniles.

In most of the Options, the bypass flows are collected in a common manifold and routed to the outfall. Two of the Options (3 & 4) utilize a continuous channel with primary and secondary dewatering. In Option 9 there is a collection flume for the bypass flows. The following matrix provides a breakdown of the specific approaches and how they apply to each Option.

Reference: n/a

WANAPUM CONCEPTIONAL DESIGNS

APPROACH / OPTIONS	1	2	3	4	5	6	7 &7A	8	9	10 &10A	11
ONE MODULE PER TWO UNITS	X	X	X	X		X	X		X		X
ONE MODULE PER UNIT					X			X			
ONE MODULE PER BAY										X	
BLOWER - TURBINE DRAFT	X		X			X					
"VENTURI" - TURBINE DRAFT		X			X			X	X	X	
UNIT 12 DRAFT				X			X				
SPILLWAY DRAFT							X				X
COMMON MANIFOLD BYPASS	X	X			X	X	X	X		X	
CONTINUOUS CHANNEL BYPASS			X	X							
THREE BYPASS INLETS PER MODULE								X			
SEPARATE BYPASS - OPEN CHANNEL									X		
NO DEWATERING											X



MODULE IN TWO-SLOT OPERATION
PLAN VIEW
SCALE: NONE

DO NOT SCALE THIS DRAWING. FOLLOW DIMENSIONS.

ATTENTION:

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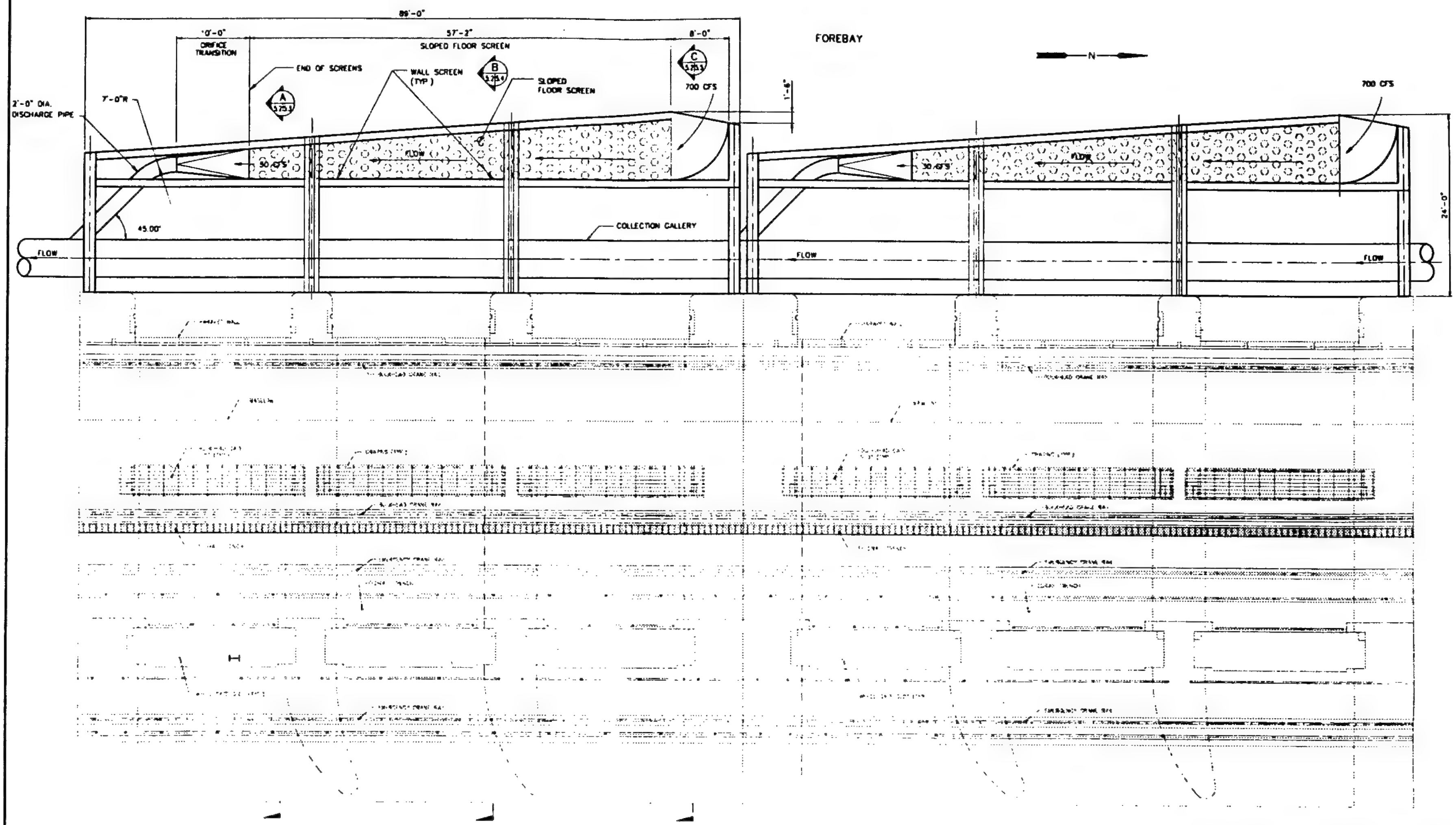
PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 6 – TWO-SLOT MODULE
PLAN VIEW A – ONE MODULE

INTERIM | CONCEPTUAL

Sverdrup CORPORATION

RDR | RDR | 430-404 | 3/10/95



PLAN VIEW
SCALE NONE

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ATTRACTION FLOW SYSTEM
OPTION 5 – VENTURI MODULES
PLAN VIEW – 2 MODULES

INTERIM | CONCEPTUAL

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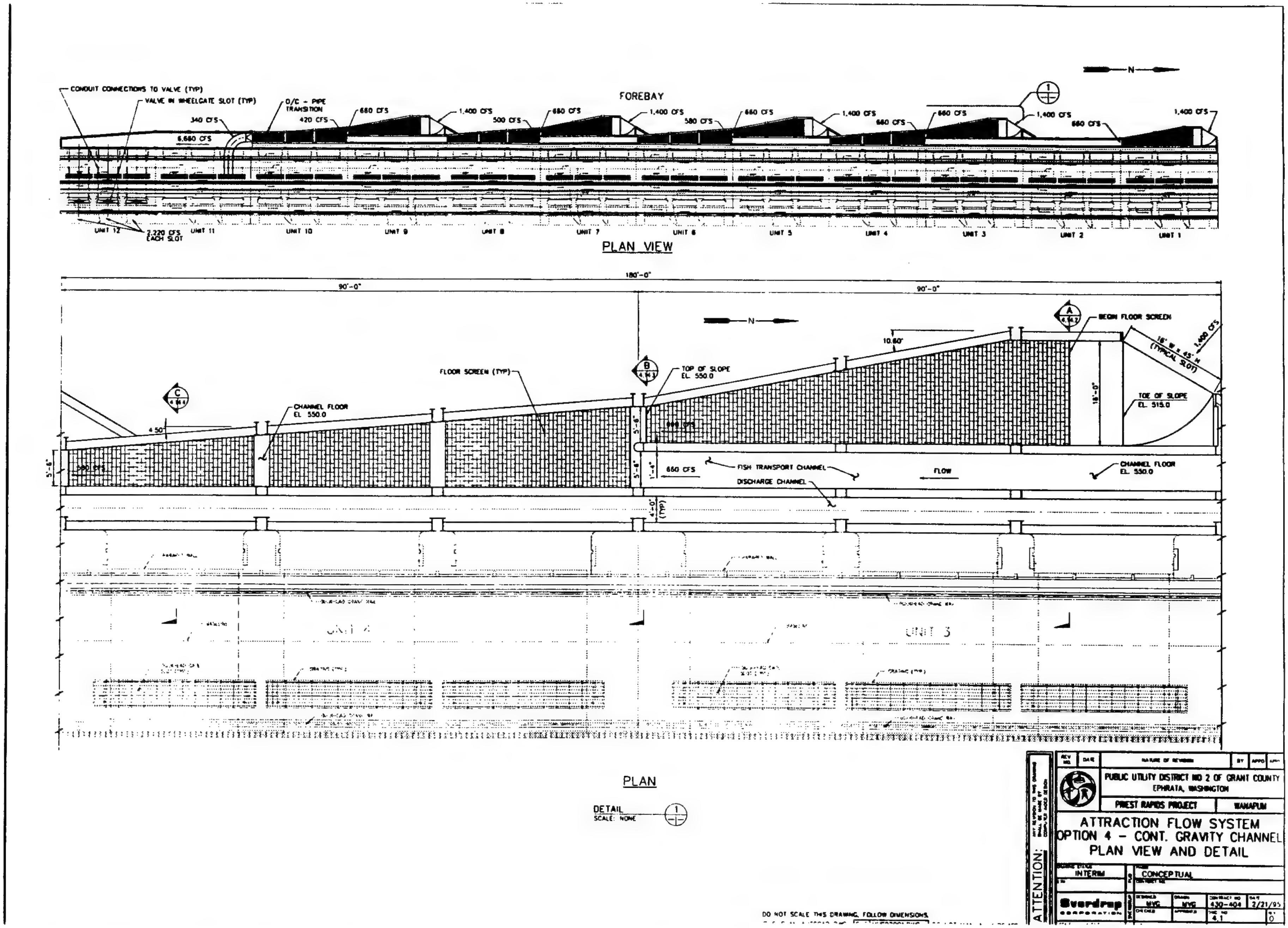

FOREBAY
CONDUIT CONNECTIONS TO VALVE (TYP)
VALVE IN WHEELGATE SLOT (TYP)
O/C - PIPE TRANSITION
340 CFS
420 CFS
6,680 CFS
680 CFS
1,400 CFS
500 CFS
580 CFS
2,220 CFS EACH SLOT
UNIT 12
UNIT 11
UNIT 10
UNIT 9
UNIT 8
UNIT 7
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
PLAN VIEW
180'-0"
90'-0"
90'-0"
BEGIN FLOOR SCREEN
18' W x 45' H (TYPICAL SLOT)
FLOOR SCREEN (TYP)
TOP OF SLOPE EL. 550.0
TOE OF SLOPE EL. 515.0
CHANNEL FLOOR EL. 550.0
10.60'
18'-0"
4.50'
5'-6"
1'-4"
4'-0" (TYP)
660 CFS
FISH TRANSPORT CHANNEL
DISCHARGE CHANNEL
FLOW
UNIT 4
UNIT 3
PLAN
DETAIL
SCALE: NONE
DO NOT SCALE THIS DRAWING, FOLLOW DIMENSIONS
ATTENTION:
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
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PRIEST RAPIDS PROJECT
WANAPUM
ATTRACTION FLOW SYSTEM
OPTION 4 - CONT. GRAVITY CHANNEL
PLAN VIEW AND DETAIL
INTERIM
CONCEPTUAL
Sverdrup CORPORATION
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430-404
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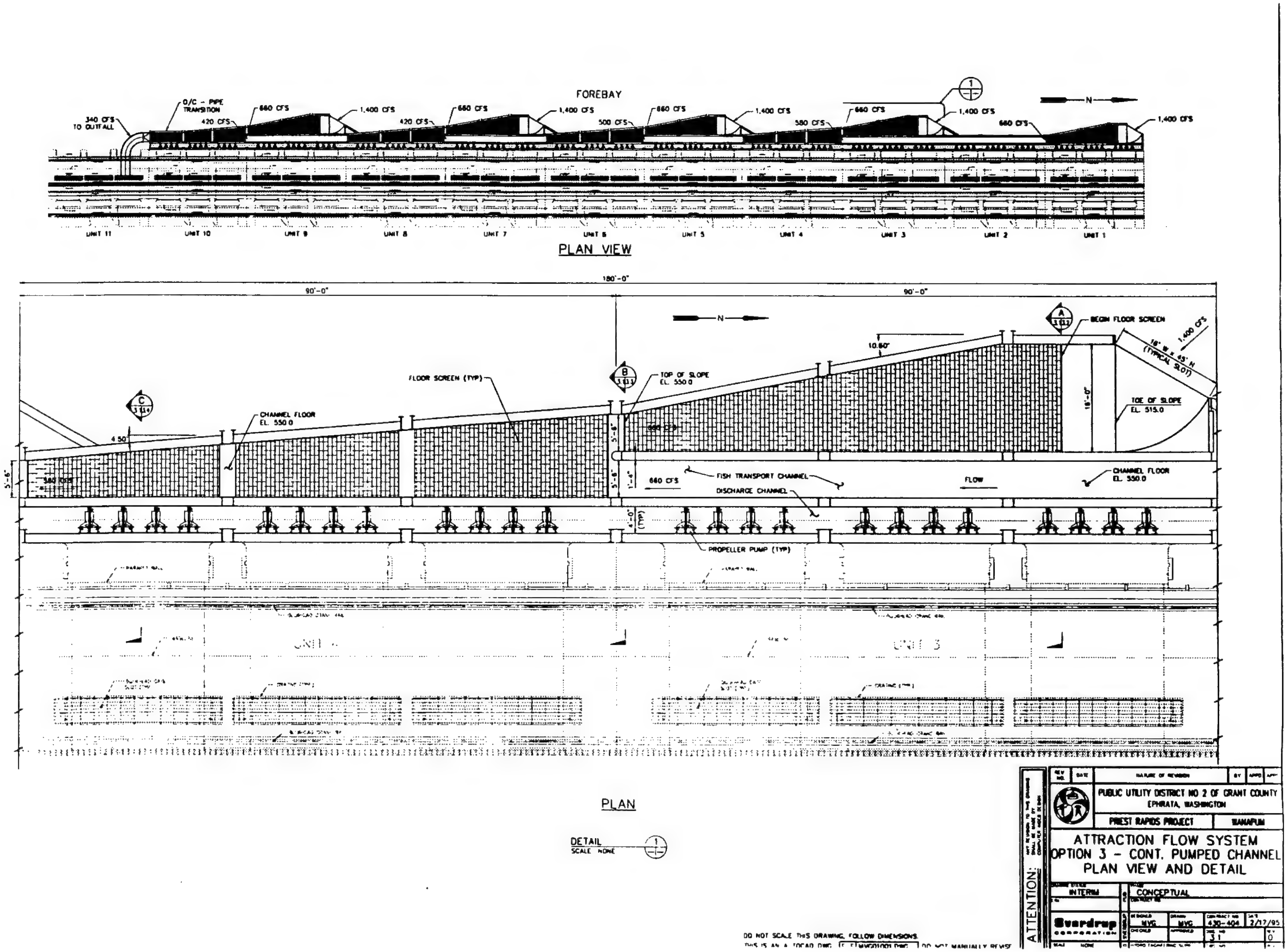

FOREBAY
340 CFS TO OUTFALL
O/C - PIPE TRANSITION
660 CFS
420 CFS
1,400 CFS
500 CFS
580 CFS
UNIT 11
UNIT 10
UNIT 9
UNIT 8
UNIT 7
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
PLAN VIEW
180'-0"
90'-0"
N
BEGIN FLOOR SCREEN
18' W x 45' H (TYPICAL SLOT)
TOE OF SLOPE EL. 515.0
10.60°
FLOOR SCREEN (TYP)
TOP OF SLOPE EL. 550.0
CHANNEL FLOOR EL. 550.0
4.50°
FISH TRANSPORT CHANNEL
DISCHARGE CHANNEL
FLOW
PROPELLER PUMP (TYP)
18'-0"
5'-6"
1'-6"
4'-0" (TYP)
PLAN
DETAIL
SCALE: NONE
DO NOT SCALE THIS DRAWING, FOLLOW DIMENSIONS.
ATTENTION:
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WANAPUM
ATTRACTION FLOW SYSTEM
OPTION 3 - CONT. PUMPED CHANNEL
PLAN VIEW AND DETAIL
INTERIM
CONCEPTUAL
Sverdrup CORPORATION
MVG
430-404
3/17/95
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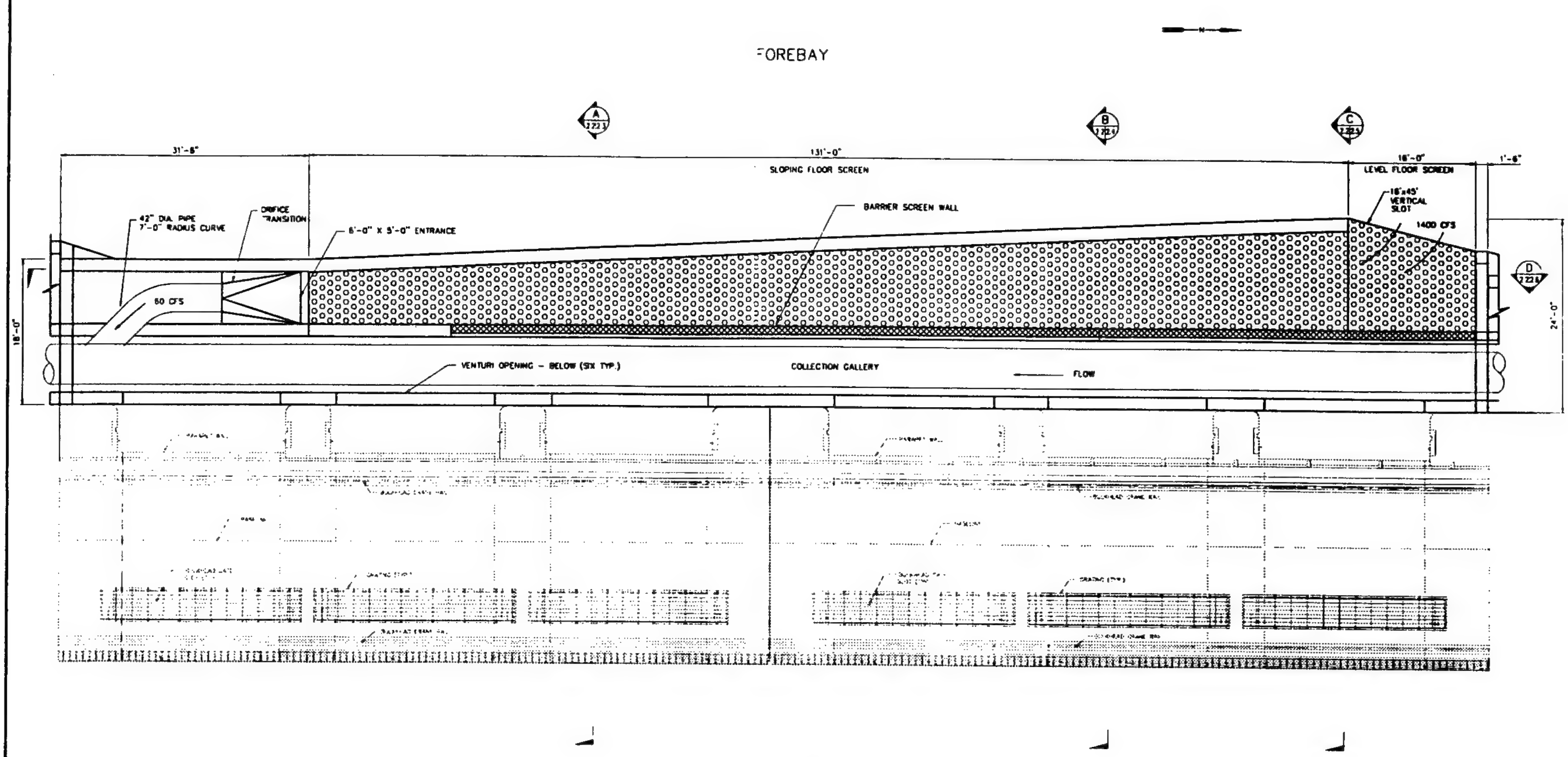

PLAN VIEW
SCALE: NONE

PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON
PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 2 - VENTURI MODULES
TYP. 2 UNIT PLAN

INTERIM | CONCEPTUAL
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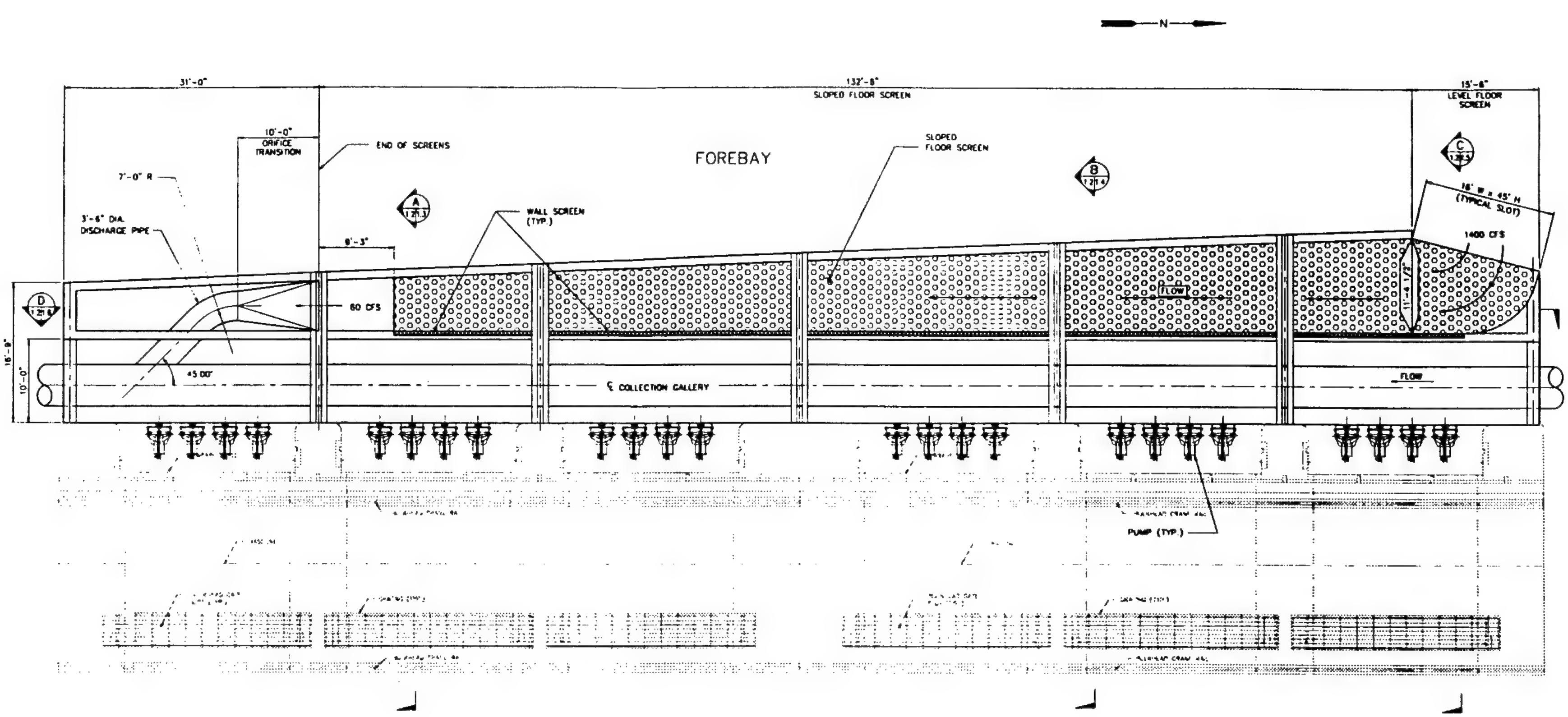

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ATTRACTION FLOW SYSTEM
OPTION 1 – PUMPED MODULES
PLAN VIEW – ONE MODULE

INTERIM | CONCEPTUAL

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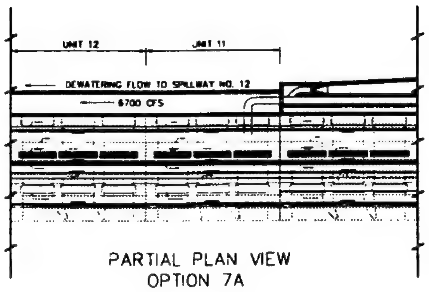
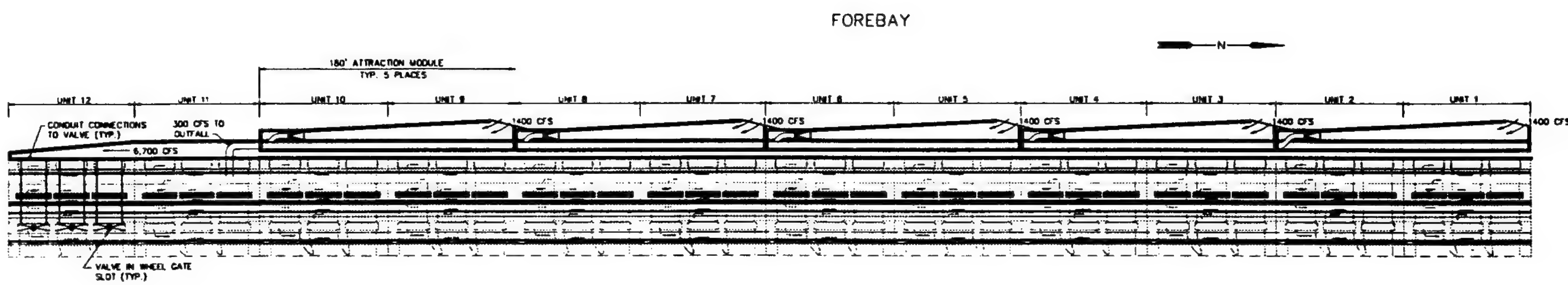


PARTIAL PLAN VIEW
OPTION 7A



OVERALL PLAN VIEW
OPTION 7 (SHOWN)
(DEWATERING FLOW DISCHARGED THRU UNIT 12)
SCALE: NONE

OPTION 7A (SIMILAR)
(DEWATERING FLOW DISCHARGED AT SPILLWAY BAY NO. 12)
(SEE DWG. 7.6 FOR DETAILS AT SPILLWAY)

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PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTIONS 7 & 7A – GRAV. DIS.
OVERALL PLAN VIEW

INTERIM | CONCEPTUAL

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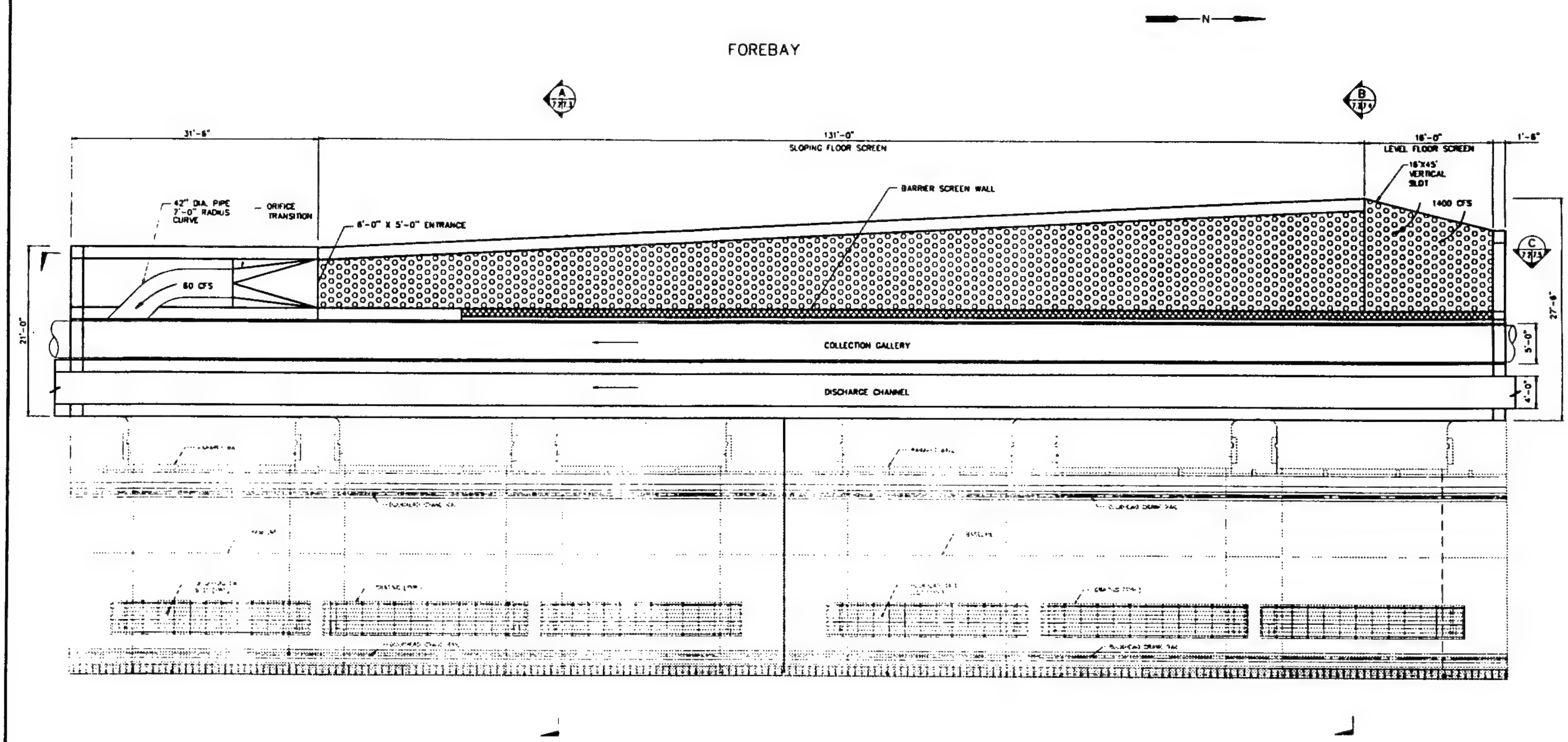

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ATTRACTION FLOW SYSTEM
OPTIONS 7 & 7A – GRAV. DIS.
TYP. 2 UNIT PLAN

INTERIM
CONCEPTUAL

Sverdrup CORPORATION

LMW 430-404 2/24/95

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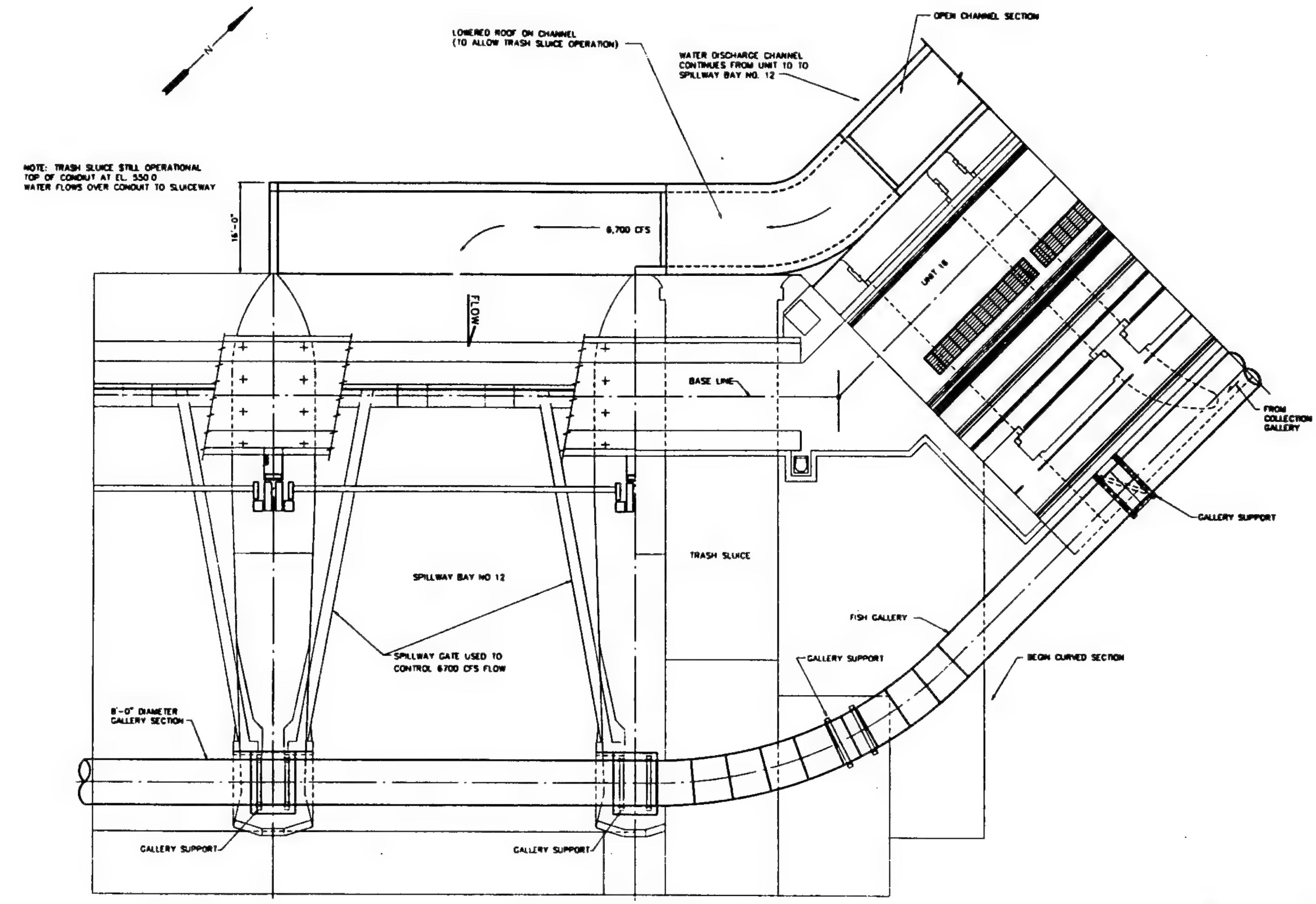

PARTIAL PLAN AT SPILLWAY BAY NO. 12

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ATTRACTION FLOW SYSTEM
OPTIONS 7 & 7A – GRAV. DIS.
PLAN VIEW AT SPILLBAY NO. 12

INTERIM

CONCEPTUAL

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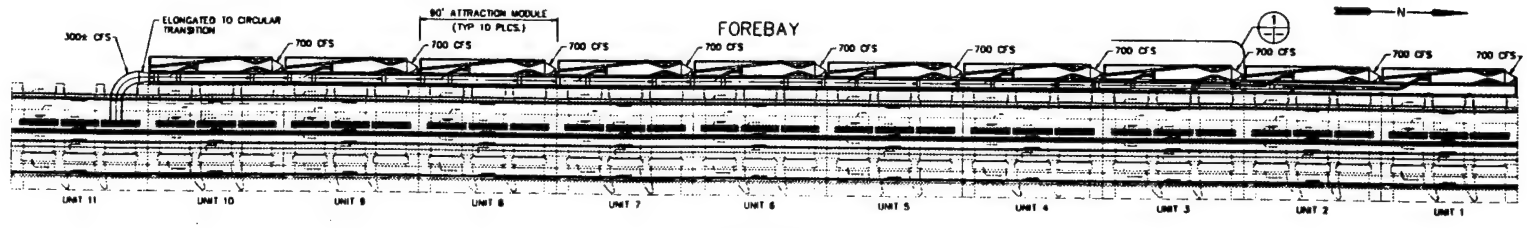

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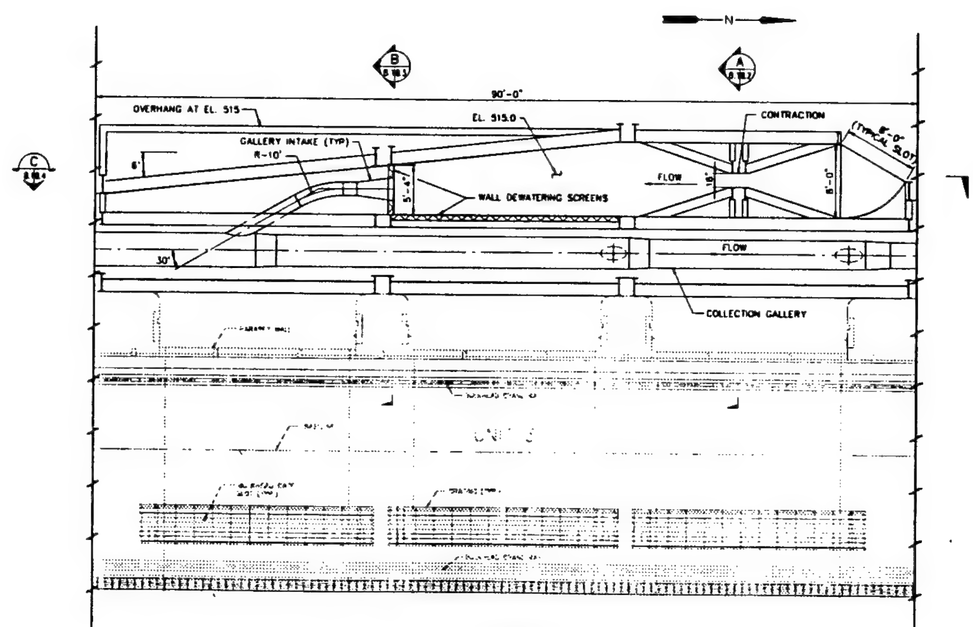

PLAN

DETAIL
SCALE: NONE

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ATTRACTION FLOW SYSTEM
OPTION 8 – 3 INTAKE TRAP CHANNEL
PLAN VIEW AND DETAIL

INTERIM
CONCEPTUAL

Sverdrup CORPORATION
MVG MVG 430-404 7/28/95
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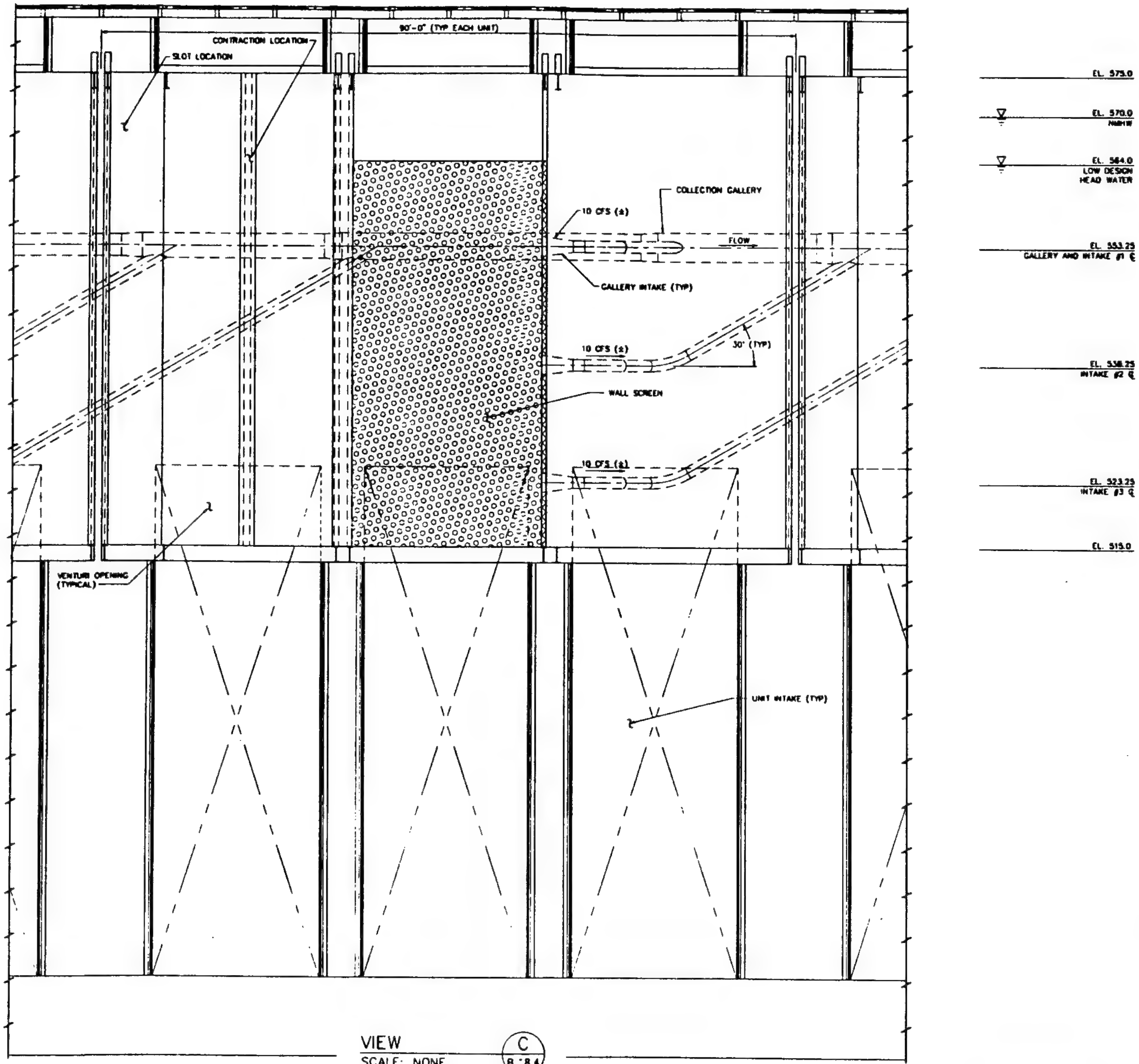

VIEW (C / B.8.4)
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PRIEST RAPIDS PROJECT — WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 8 – 3 INTAKE TRAP CHANNEL
DEVELOPED ELEVATION

INTERIM — CONCEPTUAL

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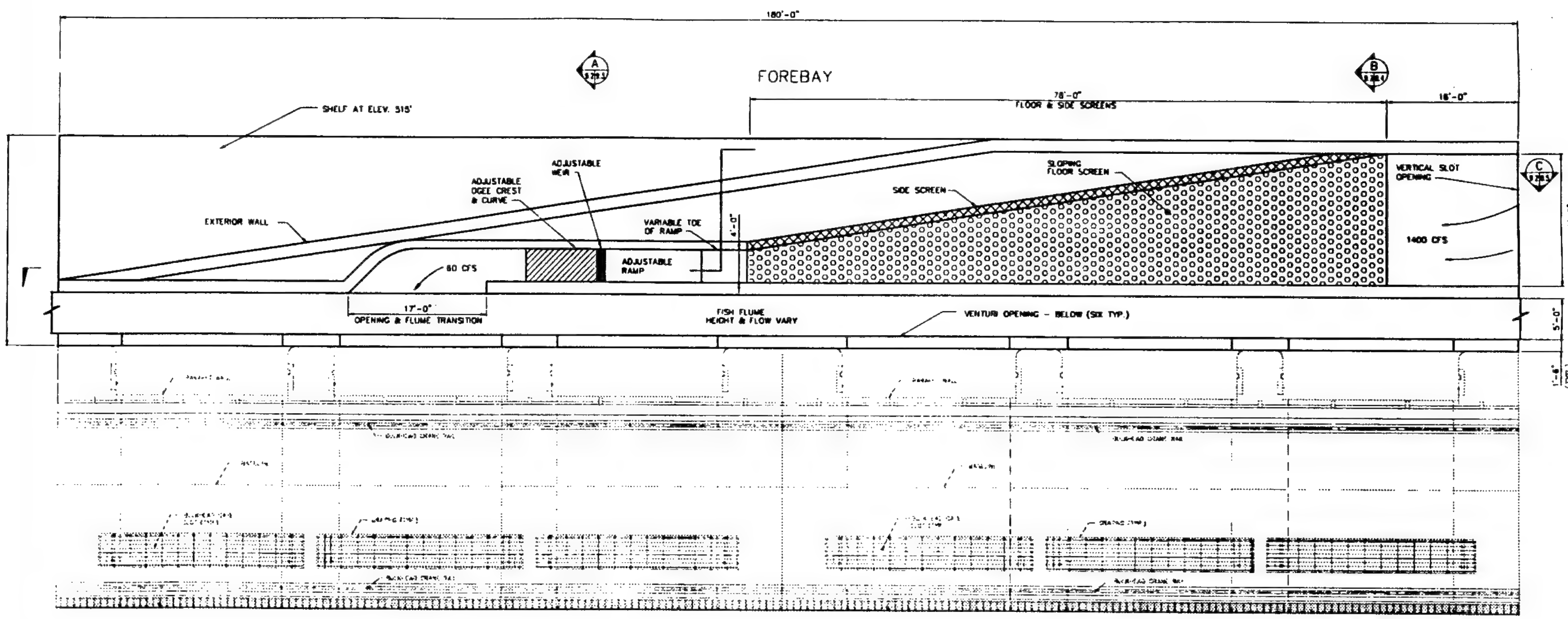

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PRIEST RAPIDS PROJECT — WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 9 - VENTURI MODULES
TYP. 2 UNIT PLAN

INTERIM — CONCEPTUAL

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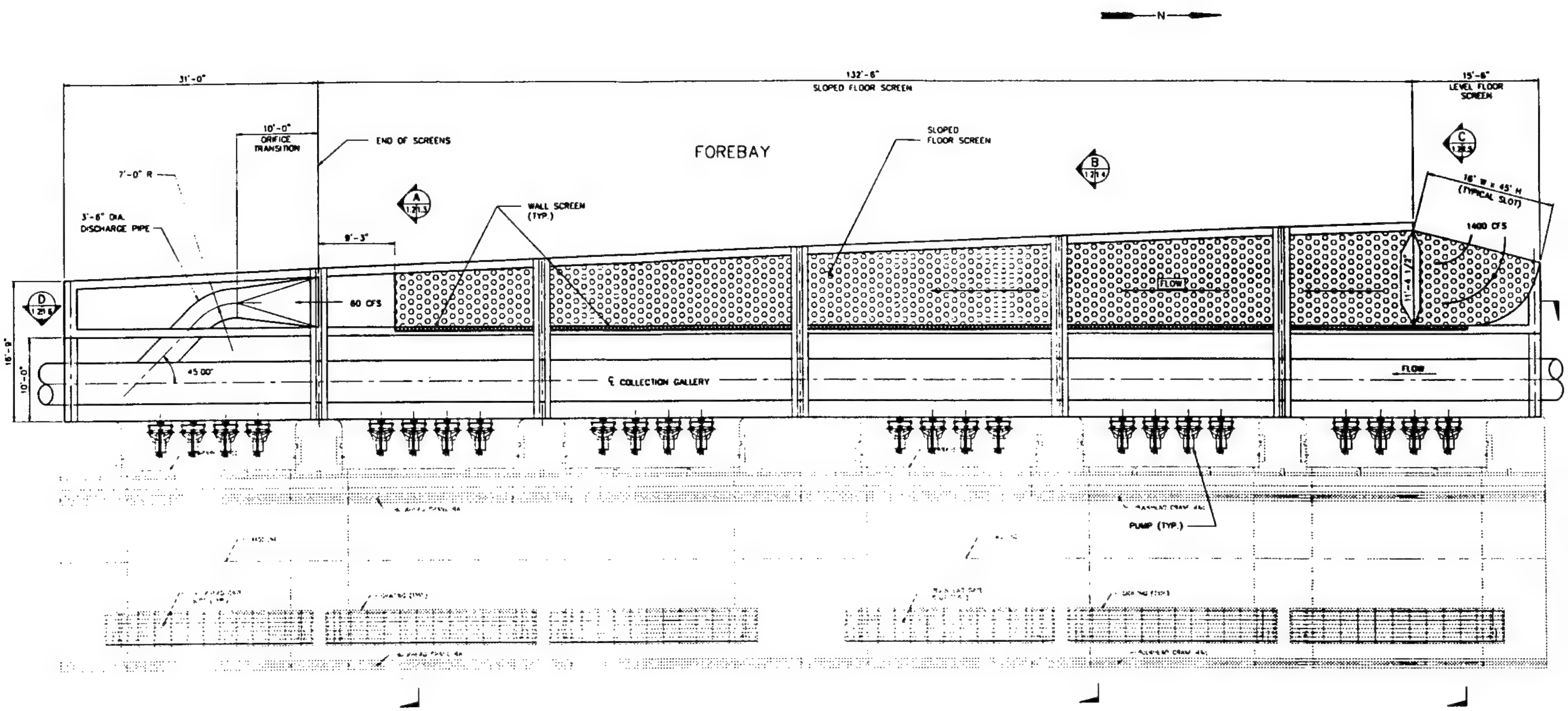

PLAN VIEW
SCALE: NONE

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PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 1 – PUMPED MODULES
PLAN VIEW – ONE MODULE

INTERIM | CONCEPTUAL

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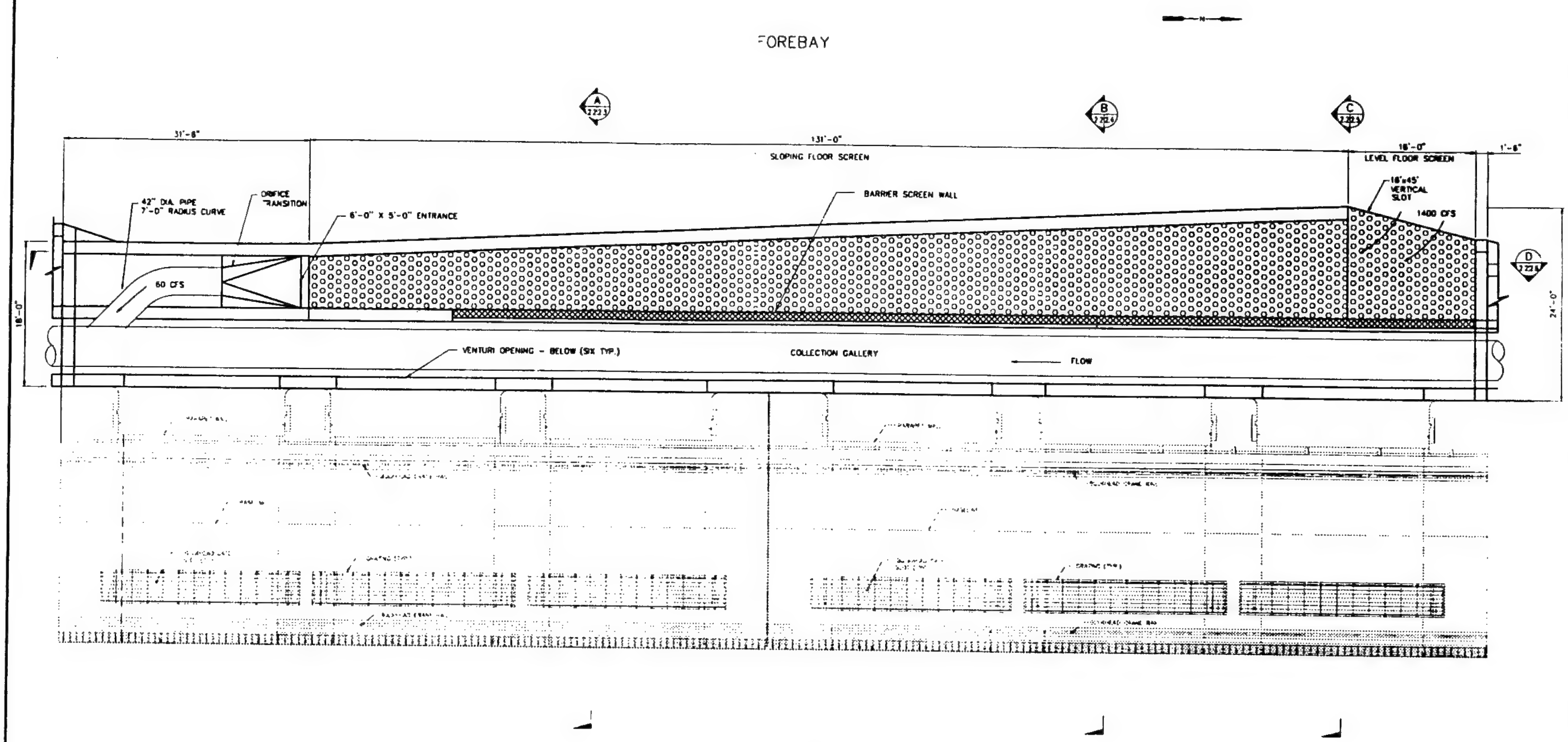

PLAN VIEW
SCALE: NONE

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PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
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PRIEST RAPIDS PROJECT | WANUPUM

ATTRACTION FLOW SYSTEM
OPTION 2 – VENTURI MODULES
TYP. 2 UNIT PLAN

INTERIM | CONCEPTUAL

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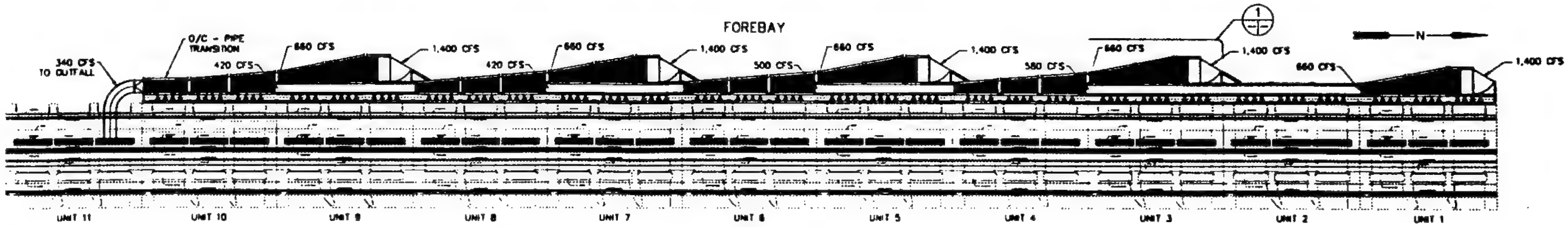
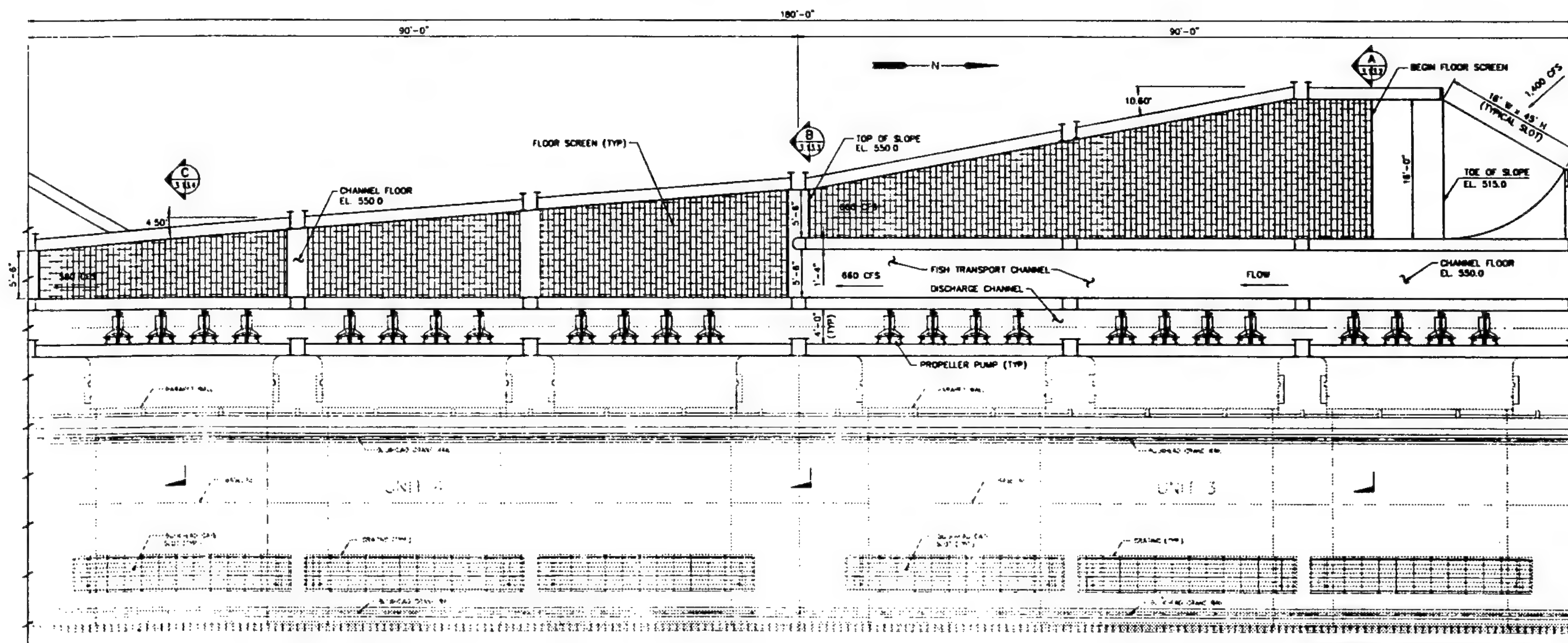


PLAN VIEW



PLAN

DETAIL
SCALE: NONE

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PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 3 - CONT. PUMPED CHANNEL
PLAN VIEW AND DETAIL

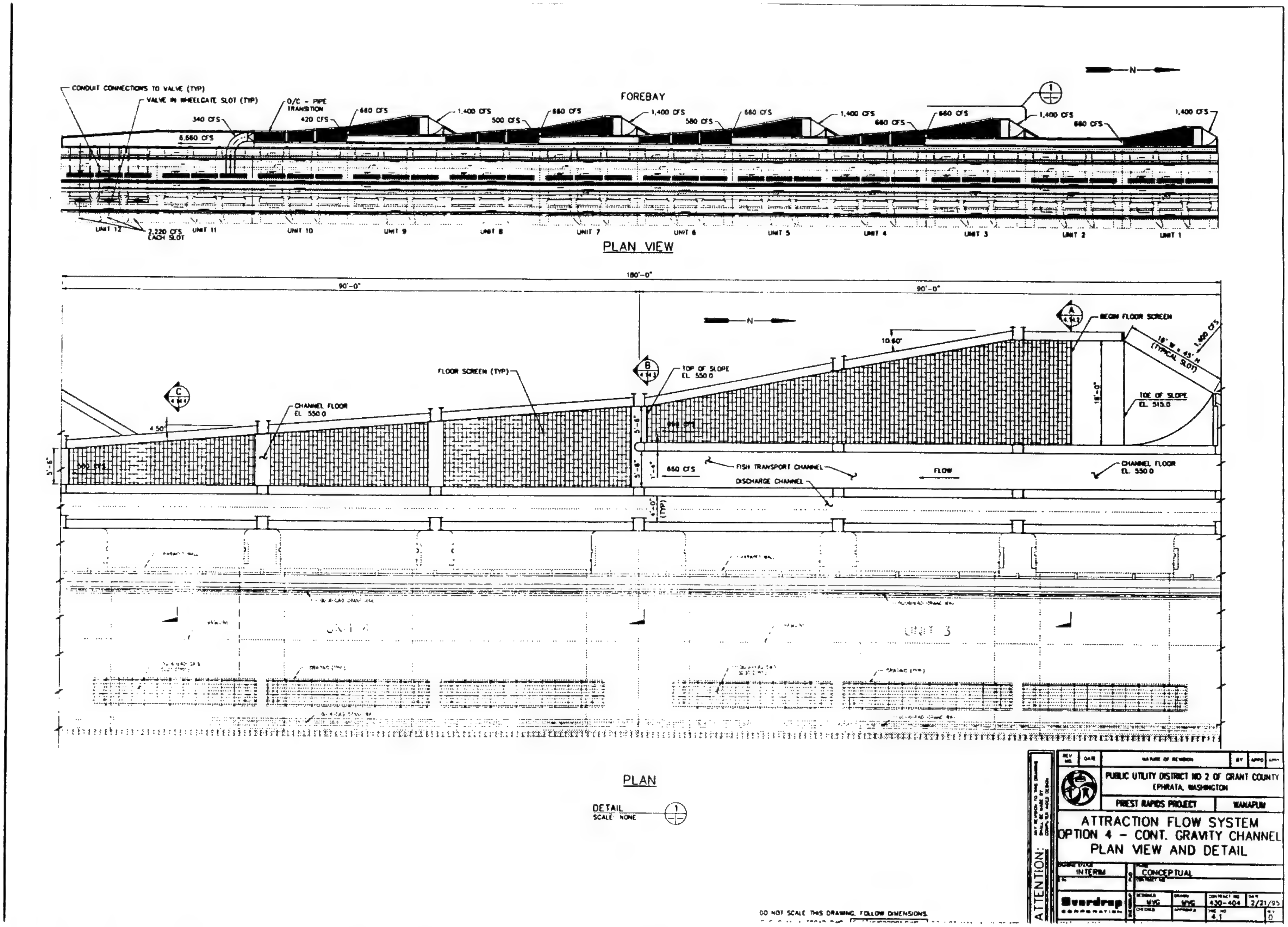
INTERIM | CONCEPTUAL

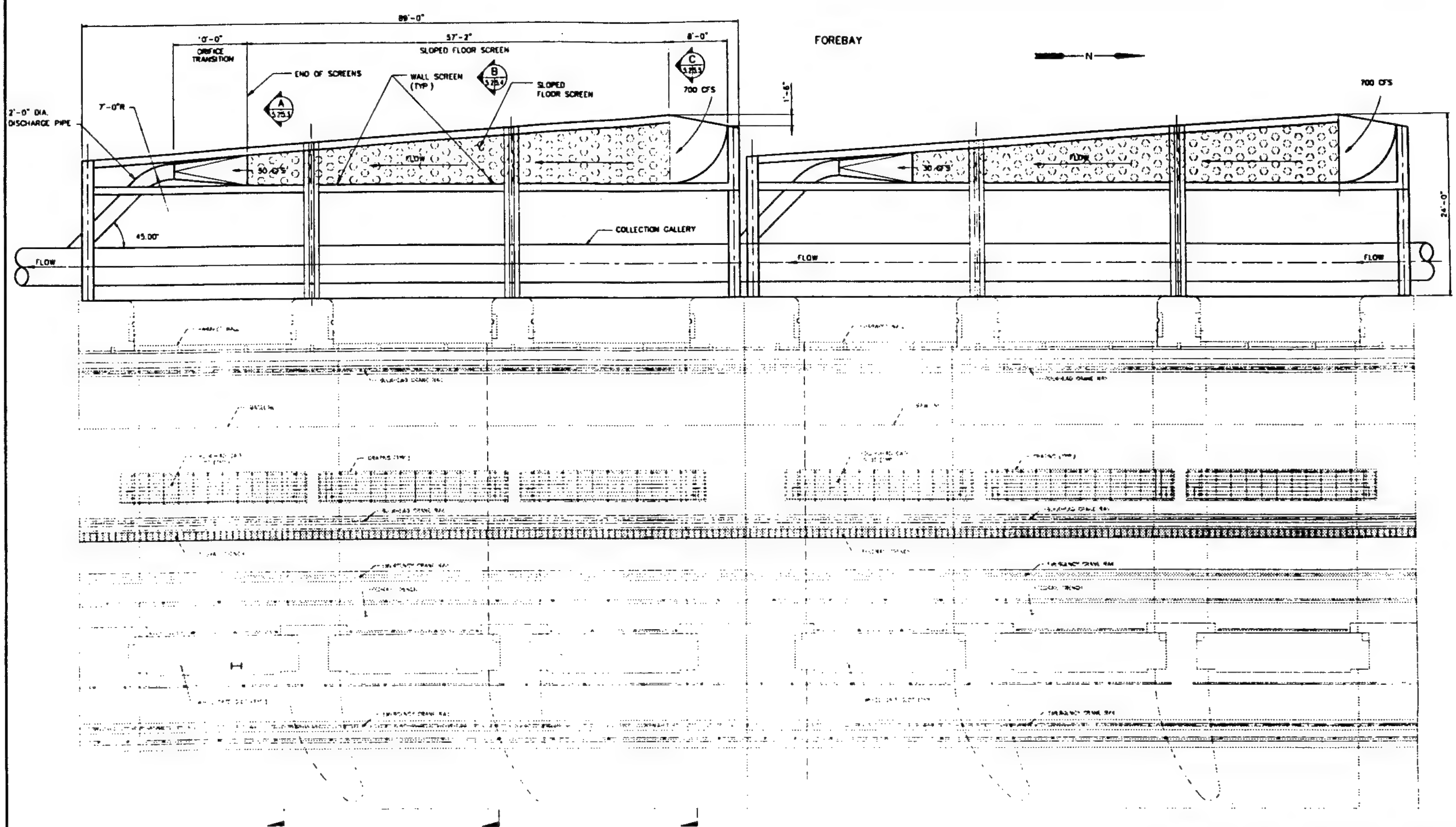
ATTENTION:

Sverdrup CORPORATION

MVG | MVG | 430-404 | 7/17/95 | 31 | 0

SCALE: NONE


FOREBAY
CONDUIT CONNECTIONS TO VALVE (TYP)
VALVE IN WHEELGATE SLOT (TYP)
O/C - PIPE TRANSITION
340 CFS
420 CFS
8,660 CFS
660 CFS
1,400 CFS
500 CFS
580 CFS
2,220 CFS EACH SLOT
UNIT 12
UNIT 11
UNIT 10
UNIT 9
UNIT 8
UNIT 7
UNIT 6
UNIT 5
UNIT 4
UNIT 3
UNIT 2
UNIT 1
PLAN VIEW
180'-0"
90'-0"
BEGIN FLOOR SCREEN
18" W x 45" H (TYPICAL SLOT)
TOE OF SLOPE EL 515.0
FLOOR SCREEN (TYP)
TOP OF SLOPE EL 550.0
CHANNEL FLOOR EL 550.0
FISH TRANSPORT CHANNEL
DISCHARGE CHANNEL
FLOW
660 CFS
10.60'
4.50'
5'-6"
18'-0"
PLAN
DETAIL
SCALE: NONE
UNIT 3
DO NOT SCALE THIS DRAWING. FOLLOW DIMENSIONS.
ATTENTION:
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON
PRIEST RAPIDS PROJECT
WANAPUM
ATTRACTION FLOW SYSTEM
OPTION 4 - CONT. GRAVITY CHANNEL
PLAN VIEW AND DETAIL
INTERIM
CONCEPTUAL
Sverdrup
MVG
430-404
2/21/95
4.1
0



PLAN VIEW
SCALE NONE

REV NO	DATE	NATURE OF REVISION	BY	APPD	APPD

PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 5 – VENTURI MODULES
PLAN VIEW – 2 MODULES

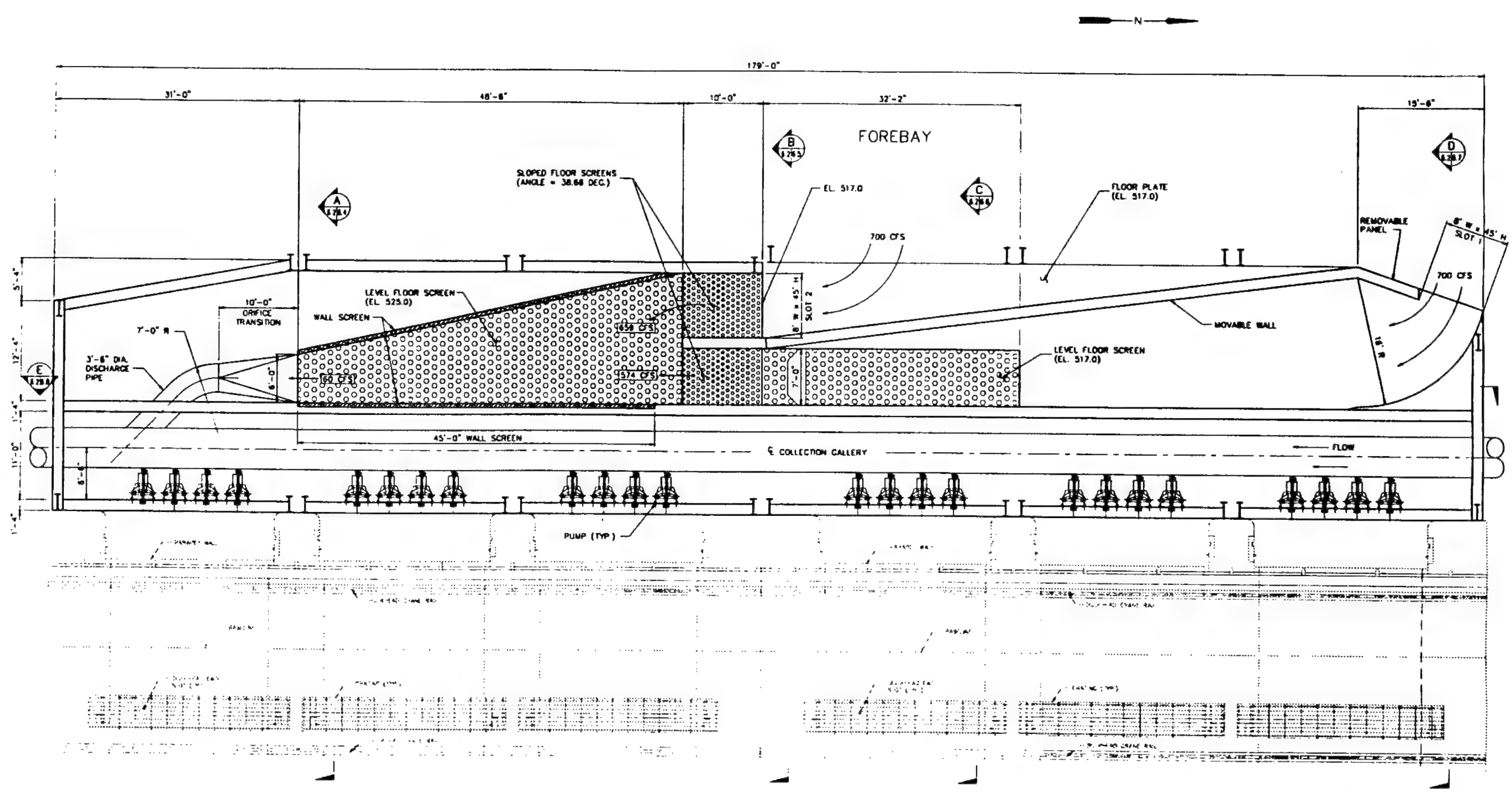
INTERIM | CONCEPTUAL

Sverdrup CORPORATION

DRAWN RGW | CONTRACT NO. 430-404 | DATE 3/7/95

ATTENTION:

DO NOT SCALE THIS DRAWING. FOLLOW DIMENSIONS.



MODULE IN TWO-SLOT OPERATION
PLAN VIEW
SCALE NONE

DO NOT SCALE THIS DRAWING. FOLLOW DIMENSIONS.

ATTENTION:

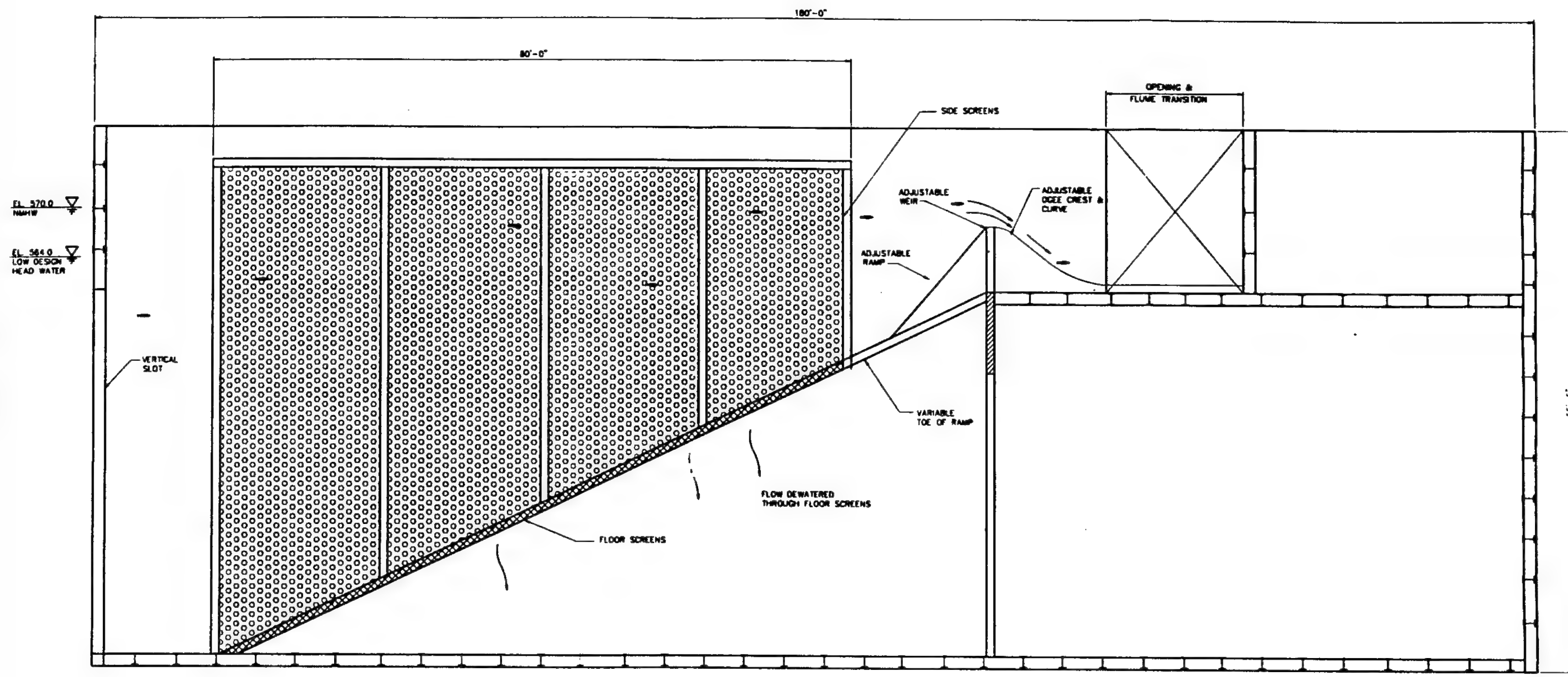
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 6 – TWO-SLOT MODULE
PLAN VIEW A – ONE MODULE

INTERIM | CONCEPTUAL

Sverdrup CORPORATION | RDR | RDR | 430-404 | 3/10/95



SECTION (C)
SCALE: NONE

DO NOT SCALE THIS DRAWING. FOLLOW DIMENSIONS.

ATTENTION:

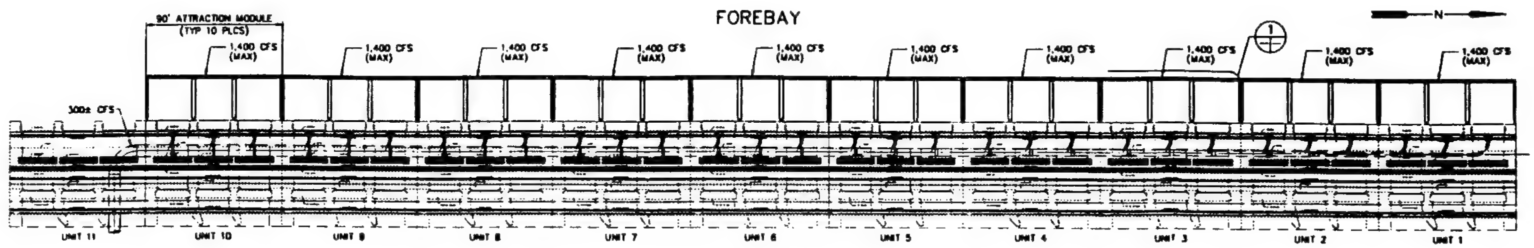
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

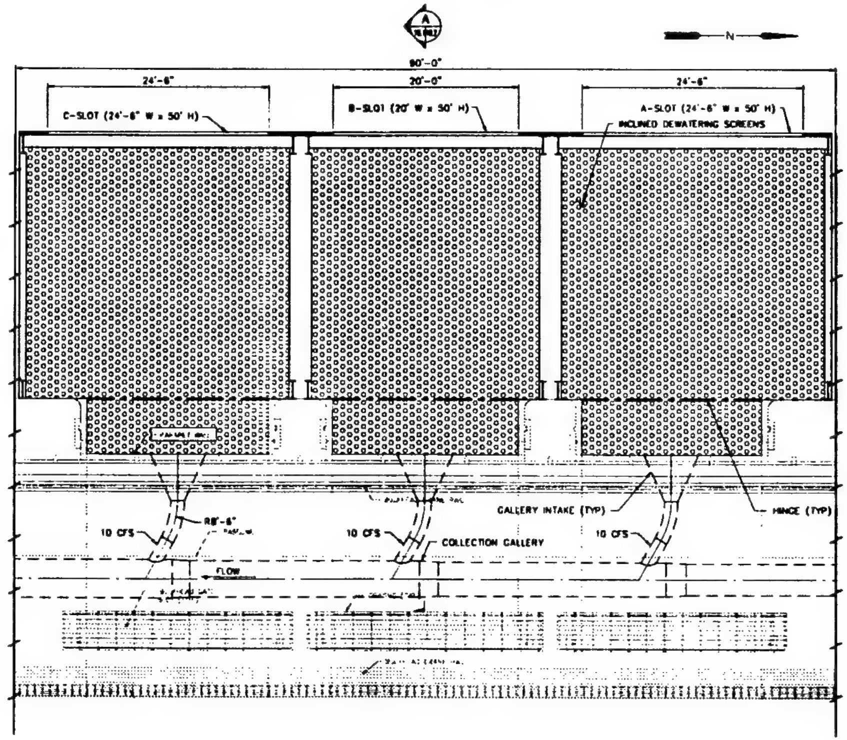
ATTRACTION FLOW SYSTEM
OPTION 9 - VENTURI MODULES
ELEVATION

INTERIM | CONCEPTUAL

Sverdrup CORPORATION | LMW | 430-404 | 2/24/95



PLAN VIEW



PLAN

DETAIL
SCALE: NONE

DO NOT SCALE THIS DRAWING, FOLLOW DIMENSIONS

ATTENTION:

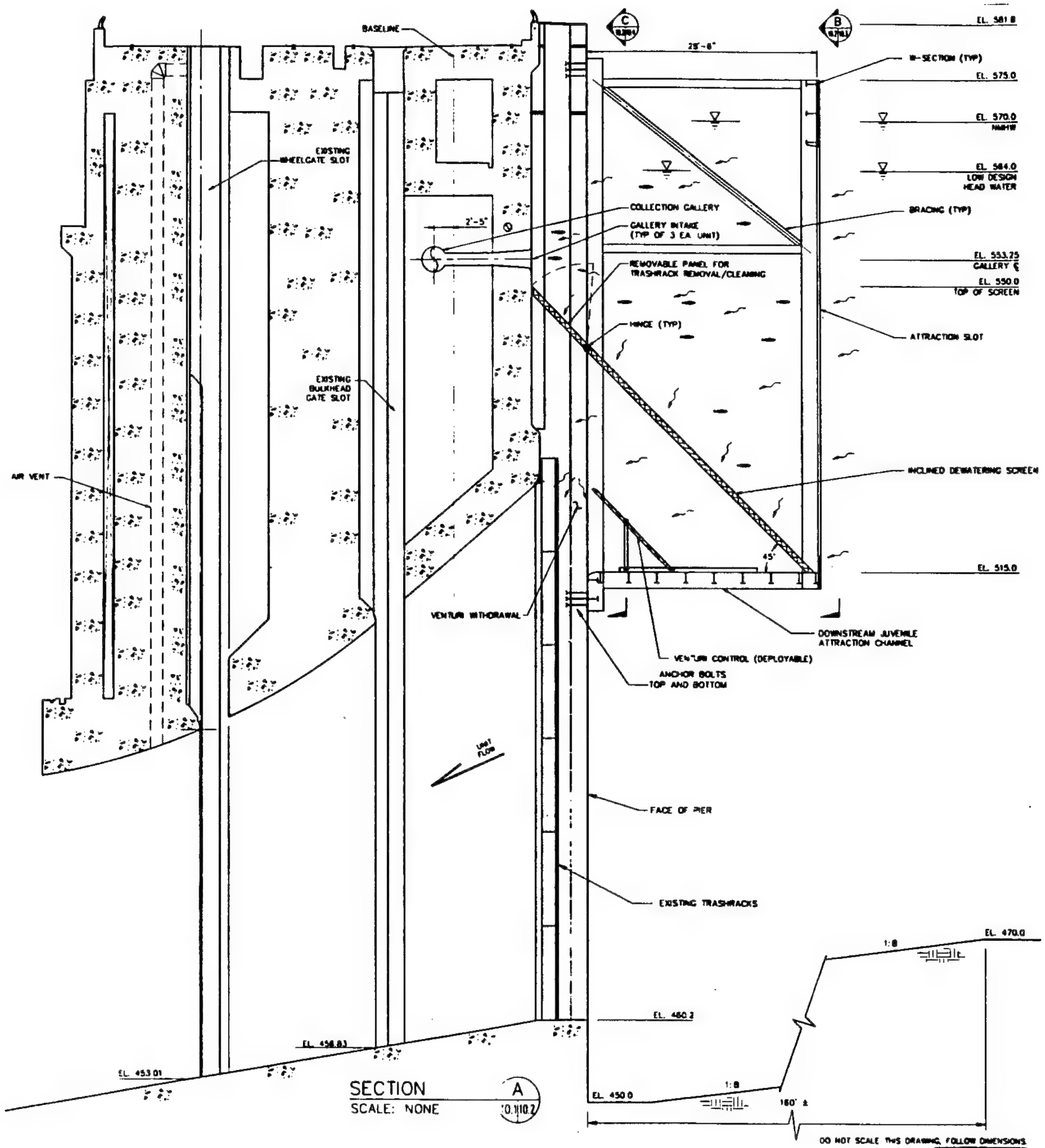
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 10 - MULTI SLOT W/ MINED GALLERY
PLAN VIEW AND DETAIL

INTERIM | CONCEPTUAL

Sverdrup CORPORATION | MVG | MVG | 430-404 | 2/28/95 | 101 | 0



ATTENTION:

PUBLIC UTILITY DISTRICT NO. 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

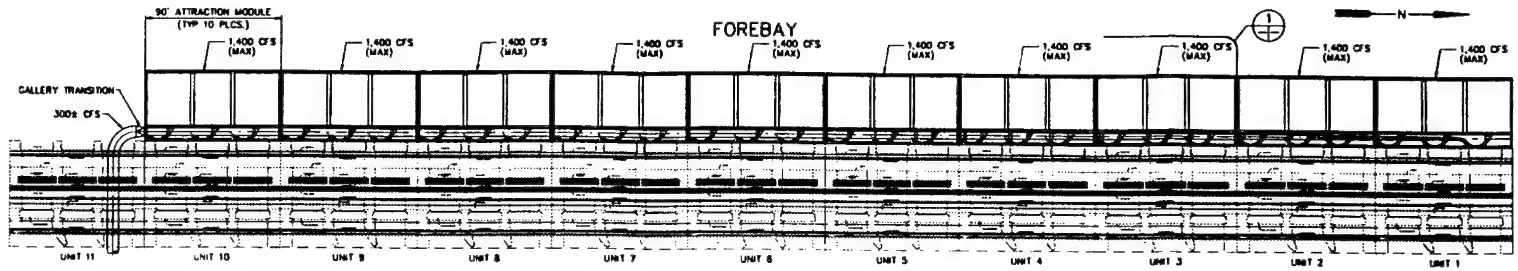
PRIEST RAPIDS PROJECT — WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 10 – MULTI SLOT W/ MINED GALLERY
MODULE SECTION

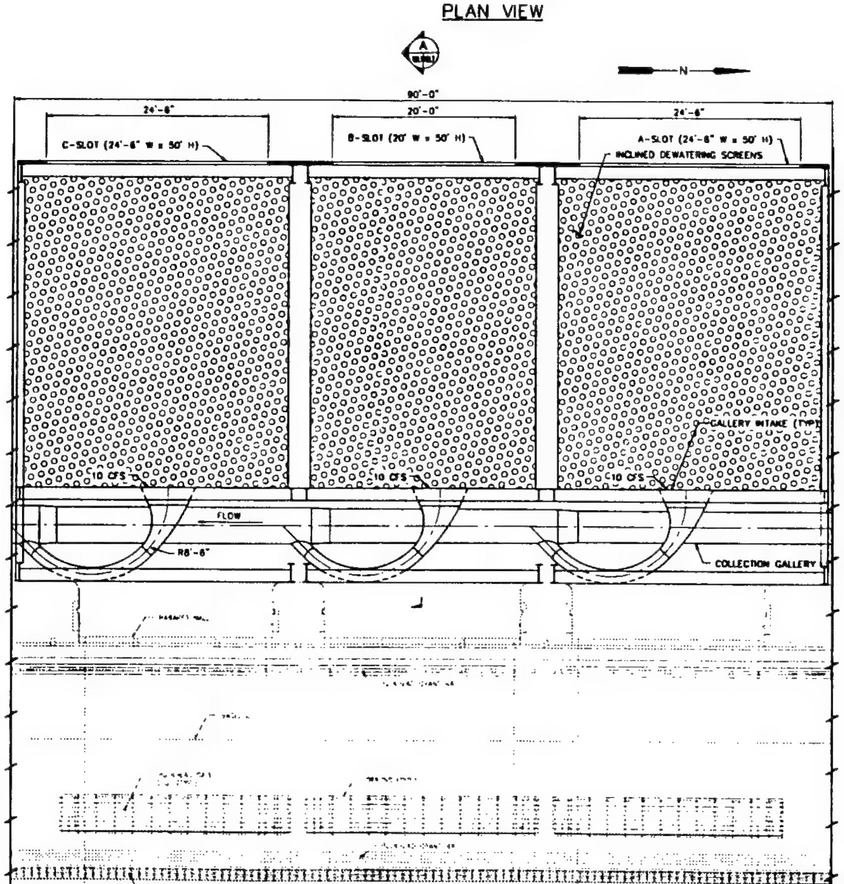
INTERIM — CONCEPTUAL

Sverdrup Corporation

Designed	Drawn	Contract No.	Date
MVG	MVG	430-404	2/28/95
Checked	Approved	Dwg. No. 10.2	Rev. 0



PLAN VIEW



PLAN

DETAIL
SCALE: NONE

DO NOT SCALE THIS DRAWING, FOLLOW DIMENSIONS.

ATTENTION:

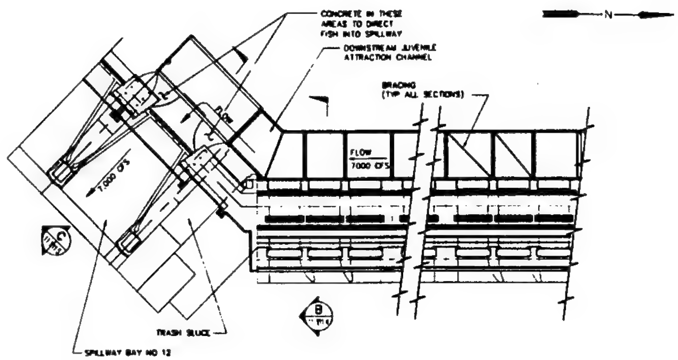
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 10A - MULTI SLOT W/ FOREBAY GALLERY
PLAN VIEW AND DETAIL

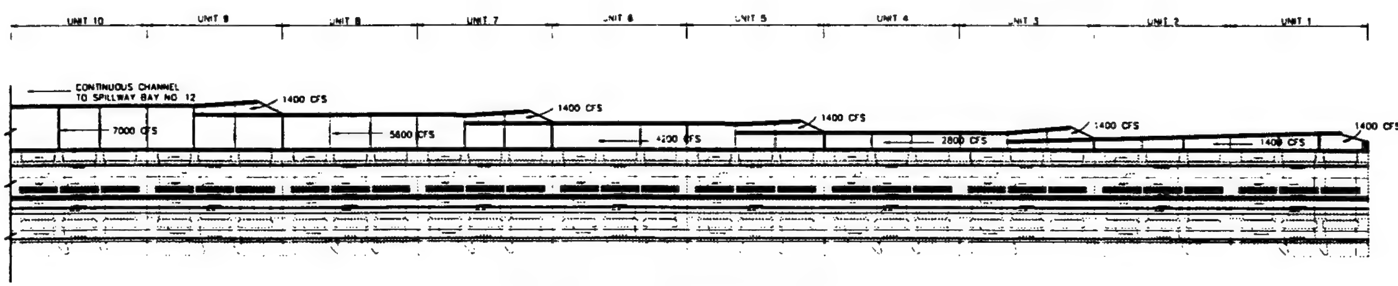
INTERIM | CONCEPTUAL

Sverdrup Corporation | MVG | MVG | 430-404 | 3/8/95 | 10A.1 | 0



PARTIAL PLAN
SPILLWAY & UNIT 16

FOREBAY



PLAN VIEW - UNITS 1 THROUGH 10

DO NOT SCALE THIS DRAWING, FOLLOW DIMENSIONS

ATTENTION:

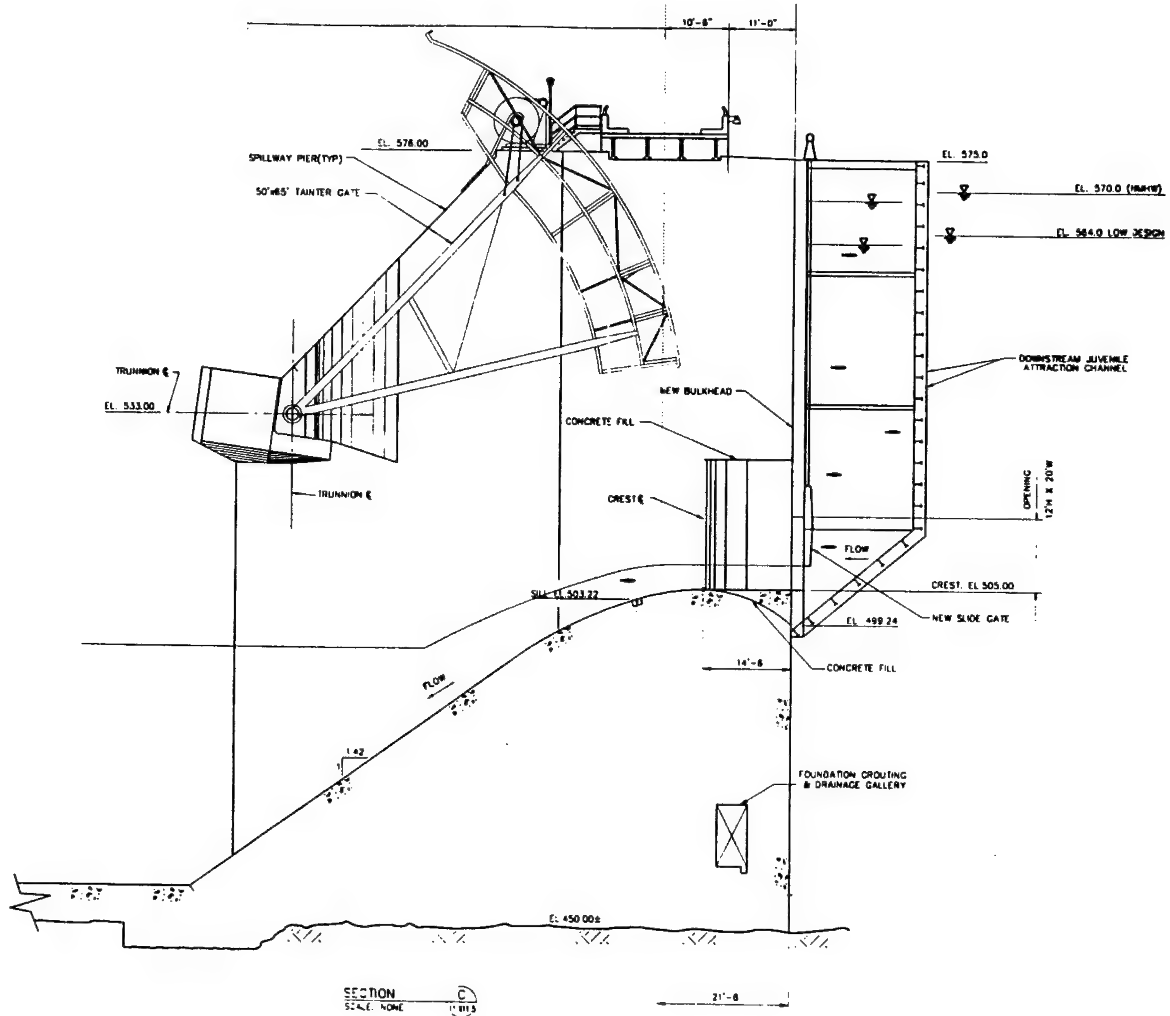
PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 11-SPILLWAY DISCH. / NO SCREENS
OVERALL PLAN VIEW

INTERIM | CONCEPTUAL

Sverdrup CORPORATION | LMW | 430-404 | 3/9/95



SECTION C
SCALE: NONE

PUBLIC UTILITY DISTRICT NO 2 OF GRANT COUNTY
EPHRATA, WASHINGTON

PRIEST RAPIDS PROJECT | WANAPUM

ATTRACTION FLOW SYSTEM
OPTION 11-SPILLWAY DISCH. / NO SCREENS
SECTION AT SPILLWAY BAY NO.12

INTERIM | CONCEPTUAL

Sverdrup | LMW | 430-404 | 3/9/95

ATTENTION:

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search Summary

Summary No. 15

Doc. 121

Reference/Title: **Fish Diversion Techniques for Hydroelectric Turbine Intakes**
Author/Document No.: **Canadian Electric Association 149 G 339**
Publication Date: **January 1984**

Document Contents:
Part 1 Introduction
Part 2 Review of Fish Protective Methods
Part 3 Canadian Perspective
Part 4 Summary of Practical or Promising Techniques

Objectives: To review available screening (largely Canadian and American) techniques or screening alternatives and evaluate then in terms of their effectiveness in preventing fish entry into turbine intakes

To identify specific screening research areas that should be addressed to improve fish passage at Canadian hydroelectric projects.

Results: Six fish diversionary techniques were identified as practical or promising. These included submersible traveling screens, Eicher pressure screens, horizontal fixed screens, inclined plane screens, louvers, and surface discharge. They note that submersible traveling screens (gatewell screens) were undergoing extensive research on the Columbia system and did not warrant additional Canadian research. The Eicher screen (high velocity screen), the inclined plane screen, and fixed screens (both horizontal and vertical) were potentially high efficiency concepts that might warrant research development. Louvers and surface discharges were identified as variable efficiency concepts that likewise warranted further research.

It is noted that when the study was conducted, screening of hydroelectric turbine intakes to prevent fish entrainment was not common in Canada and was not justified except on rivers supporting valuable runs of migratory fishes.

Citing personal communications with A.V. Holden and E. Twomey, evaluations in Scotland and Ireland have shown that delayed smolt passage from forebays results in substantial predation which was believed to cause greater losses than those inflected by turbine passage. [pp. 2-14]

Three facilities are cited that have effectively used surface bypass with Atlantic salmon smolt. Farwell (1972) describes two hydroelectric installation on the Exploits River in Newfoundland, one having a surface bypass and one without. Observations indicate that smolt migrating close to the surface were attracted to the funneling of the surface flow towards a gate located at the downstream end of the forebay which greatly expedited passage. Likewise two floating skimmers are described that effective guide Atlantic salmon smolt to surface bypasses (Semple, 1979 and Resource Development Branch, 1975). [pp.2-31 to 2-33]

Dewatering Findings

Although this document reviews both Canadian and American installations, its uniqueness lies in its wider presentation of Canadian experience. Presentations on American installations basically reiterates information presented in the EPRI documents. As a consequence this summary concentrates on details on Canadian installations.

The fish diversion systems described and evaluated in this document include: revolving drum screens, inclined plane screens, vertical traveling screens, horizontal traveling screens, vertical fixed screens, horizontal fixed screens, Eicher screens, Finnigan screens, and louvers.

Velocity and screen opening size criteria is discussed. Clay (1961) recommends that for protection of newly emerged salmon fry approach velocities should be limited to 12 cm/s (0.37 ft/s) and recommends maximum approach velocities on 30.5 cm/s (1.0 ft/s) for smolt of 80 mm or more in length. The approach velocities developed by Clay (1961) were derived from experimental cruising speed data obtained for various species of Pacific salmonid from field experience. Blaxter (1969) presents a review of research on fish swimming speeds and provides experimental results on several freshwater and marine species. He concludes that most species can maintain cruising speeds of between 2 and 3 body lengths per second but that salmonids and clupeids can probably maintain speeds of 4 body lengths per second or more. The report notes that the 12 cm/s velocity criteria was derived to protect salmon fry from impingement in flows at right angles to a wire mesh. The idea was that fry could swim at this rate for 10 minutes, during which time fry would find a bypass to one side of the screen. The benefit of sweeping velocities was not considered. Clay (1961), based on experimental tests and field monitoring recommends wire screen with square openings with a side length of 2.5 mm for newly emerged salmon fry, 3.1 mm for larger salmon fry, 3.8 mm for 50 mm long fingerlings and 20 mm for yearlings or smolts 90 - 150 mm long. [pp. 2-3 and 4-5]

Kupka (1966) describes successful use of an inclined plane screen. The screen used on the intake to Robertson Creek Channel in British Columbia was cleaned by a continuous chain of pliable blushes. It is suggested that inclined plane screen technology could be improved by identifying species and life stage specific screening materials. [pp.2-8 to 2-9 and 4-10]

Both horizontal and vertical fixed screens (similar to floor and wall screens in dewatering facilities) are described as being effective at sites in particular where suspended debris is negligible. Fixed screens have been used at small hydroelectric plants in Europe and Eastern Canada to prevent fish entry into turbine intakes. Clay (1961) notes that a simple fixed screen installation has been effective at a small thermal-electric generating plant on the Fraser River at Port Mann, British Columbia. Likewise the Fish and Wildlife Branch of the B.C. Department of Environment uses fixed horizontal screens to sample downstream migrating salmonids in natural streams and to excluding fish from irrigation withdrawals. They have found the fixed horizontal screens to be self cleaning under most conditions. The screens are typically installed in a sweeping velocity field. The horizontal screens offer the benefit of being fully submerged which maintains the full screen area in active filtration even in relatively shallow water. The Finnigan screen is a fixed horizontal screen that is cleaned by paddle wheel powered brushes. Slaney (1977) reported that salmonid fry avoid the screens and that 95 to 99% of migrating salmonid fry passed over large-aperture horizontal screens, the dimensions of which would allow fry to pass through. [pp.2-14 to 2-16 and 4-8]

V-arrangement louvers have been used in the diversion canal of the Ruth Falls power plant on the East River, Sheet Harbour, Nova Scotia. A similar arrangement has also been used at Robertson Creek in British Columbia. The Ruth Falls facility was evaluated and found to be 85% efficient with exclusion of Atlantic Salmon (Ducharme pers. comm.). Louvers are recommended in particular for sites with relatively high approach velocities, uniform flow, and relatively shallow depths (such as on power canals). They are recommended particularly where large flows are involved. Development of louvers that screen only the surface flow is proposed. [pp. 2-23 to 2-27 and 4-10 to 4-13]

Document Reference List

Importance Level: A = High B = Moderate C = Low

Importance	Document Reference No. and Title
A	Blaxter, J.H.S. <u>Swimming Speeds of Fish.</u> Proc. of FAO Conf. on Fish Behavior. Bergen Norway, Oct. 19-27, 1967. FAO Fish Rep. Vol. 62(2):69-100, 1969
AA	Clay, C.H. <u>Design Of Fishways and Other Fish Facilities.</u> Dept. Fish. Can., Ottawa, 1961.
A	Farwell, M.K. <u>Downstream Migrant Fish Problems Associated with Hydroelectric Facilities on the Exploits River.</u> Res. Dev. Br. Newfoundland. Progress Report No. 86. 1972.

B Kupka, K.H. A Downstream Migrant Diversion Screen. Can. Fish. Cult. (37):27-34, 1966.

A Resource Development Branch. Report for 1974. Fisheries and Marine Service, Halifax, 1975.

A Semple, J.R. Downstream Migration Facilities and Turbine Mortality Evaluation, Atlantic Salmon Smolts at Malay Falls, Nova Scotia. Can. Fish and Mar. Serv. Man. Rept. No. 1541, 1979.

B Slaney, K.A. An Evaluation of a Diversion Screen Design and an Assessment of Fish Losses in Irrigation Diversions of Loon Inlet Creek, British Columbia. B.C. Fish and Wildl. Br., Fish. Mang. Rept. No. 68, 1977.

Cited Personal Communications:

Ducharme, A. Biologist. Canada Fisheries and Oceans. Fisheries Research Branch, Halifax, N.S. B3J 2S7

Holden, A.V. Director, Freshwater Fisheries Laboratory, Faskally, Pitlochry, Scotland. PH16 5LB.

Twomey, E. Biologist. Department of Fisheries and Forestry. Fisheries Research Centre, Abbotstown, Castleknock, County Dublin, Ireland.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 16

Document No. 60

Reference/Title:	Clogging, Cleaning, and Corrosion Study of Possible Fish Screens for the Proposed Peripheral Canal
Author/Document No.:	Smith, Lawrence W.
Publication Date:	September 1982

Document Contents

Introduction: The intake to the proposed canal offers several challenges for fish screen design. The maximum diverted flow is large - 21,800 cfs. Fish must be excluded from the canal and returned to the river without direct mortality or undue fatigue, injury or delay.

Conclusions: Comparing screens of similar fish screening efficiency, woven wire mesh took about one and one half times longer to clog than perforated plate and welded wedge-wore slotted screen took about three times longer to clog than perforated plate. A positive correlation found between river flows and screen clogging rates can be used to predict required cleaning frequency.

Cleaning tests indicated all screens can be cleaned with water jet spray or wiper brush. The most effective was water spray with the screen out of the water. When the Sacramento River is flowing at 75,000 cfs, perforated plate may have to be cleaned as often as every hour and wedge-wire as often as every 5.3 hours to maintain screen head loss at less than 0.2 feet with a design approach velocity of 0.2 fps.

Perforated plate and welded wedge-wire screens made of type 304 stainless steel had no measurable corrosion after being submerged in the river for four years.

Reference: Smith, L.W. and D.A. Ferguson, 1979, "Progress Report on Clogging, Cleaning, and Corrosion Studies of Possible Fish Screens for the Proposed Peripheral Canal", California Department of Water Resources for the Inter-agency Ecological Study Program for the Sacramento-San Joaquin Estuary.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search

Summary No. 17

Document No. 144

Reference/Title: Some Design Considerations for Approach Velocities at Juvenile Salmonid Screening Facilities

Author/Document No.: Pearce, R.O. and R.T. Lee

Publication Date: American Fisheries Society Symposium 10:237-248, 1991

Document Contents

Abstract: The size, and therefore the cost, of screening facilities required at water diversion sites is primarily determined by the allowable approach velocity of water at the screen mesh. General screening criteria established by fisheries agencies specify maximum approach velocities. In addition to biological factors, proper attention must be given to engineering factors including uniform velocity distribution at the screen facility. Providing basic screen facility hydraulics necessary for effective fish protection requires careful attention to channel configuration and frequently involves use of baffles and training walls to control direction of flow and magnitude of velocity.

Text: Agency developed approach velocity criteria based on two size groups of fish; fry (< 60 mm in length) and fingerling (≥ 60 mm in length), are listed below:

Agency (Department)	Approach Velocity (fps) [a] Fry [b]	Fingerlings [c]	Transport Velocity (fps) [d]
NMFS	≤ 0.4	≤ 0.8	Greater than approach velocity
California (Fish & Game)	≤ 0.33[e]	Same as Fry	Min. twice the approach velocity
Oregon (Fish & Wildlife)	≤ 0.5	≤ 1.0	Approach velocity or greater
Washington (Fisheries)	≤ 0.4	≤ 0.8	Approach velocity or greater
Alaska (Fish & Game)	≤ 0.5	Same as Fry	No criterion
Idaho (Fish & Game)	≤ 0.5	≤ 0.5	Sufficient to avoid injury to fish
Montana (Fish, Wildlife & Parks)	≤ 0.5	≤ 1.0	No criterion

a Velocity component perpendicular to and approximately 3 inches in front of screen face.

b Fish less than 2.36 inches (60 mm) long.

c Fish 2.36 inches (60 mm) or longer.

d Theoretical velocity vector along and parallel to the screen face; also called sweeping velocity.

e For continuously cleaned screens, ≤ 0.0825 for intermittently cleaned screens.

The angle of approach flow, required screen area and uniform flow distribution are all equally important engineering and design considerations for the design of any screening facility. Nonuniform flow through screen sections caused by varying headlosses are determined by screen geometry, scale effects and the screen orientation with respect to the direction of flow.

Conclusions: Review of numerous fish screen designs for both proposed and existing facilities shows that a common design flaw is poor flow conditions in the critical area immediately upstream of the screen face. Both the magnitude and direction of water velocities must be controlled within prescribed limits to assure that fish are not impinged upon the screen and are quickly guided by the flow pattern to a bypass. Channel configurations both upstream and downstream of the screen mesh must provide smooth transitions, preventing eddies and other areas of nonuniform velocities. Careful hydraulic analysis, including physical modeling when appropriate, can provide desired flow conditions with minimum associated head loss. Providing flow vanes upstream of the screen or baffles immediately downstream of the screen (or both) at facilities where poor flow patterns cause passage problems can frequently rectify damaging situations at minimal cost.

Reference: Stefan, H. and A. Fu. 1978. "Headloss Characteristics of Six Profile Wire Screen Panels." University of Minnesota, St. Anthony Falls Hydraulic Laboratory, St. Anthony Falls.

U.S. Army Corps of Engineers - Walla Walla District
Juvenile Fish Surface Bypass and Collection System Studies
Dewatering System Literature Search Summary

Summary No. 18

Document No. 153

Reference/Title:	**Hydraulic Model Evaluation of the Eicher Passive Pressure Screen Fish Bypass System**	
Author/Document No.:	**EPRI AP-5492**	
Publication Date:	**October 1987**	

Document Contents:	Section 1	Introduction
	Section 2	Hydraulic Description and Test Procedures
	Section 3	Results
	Section 4	Discussion
	Section 5	Conclusions
	Section 6	Recommendations for Further Study
	Section 7	References
	Appendix A	Hydraulic Data Used in Model Evaluation
	Appendix B	Fish Behavior During Test Sequences
	Appendix C	Hydromer Coating
	Appendix D	A Generic Evaluation Procedure to Assess the Effects of a Passive Pressure Penstock Screen in Prototype

Objectives: To conduct laboratory tests of the Eicher fish screen under a variety of conditions and to determine any fish mortality, descaling and impingement.

Approach: In initial tests, researchers installed a stainless steel wedgewire screen measuring 6 x 92 in. in a Plexiglas conduit. They measured velocity profiles and pressure at several locations along the conduit to evaluate the screen's hydraulic performance. The team then brought hatchery fish to the lab, holding them 72 hours to ensure a healthy stock. They released the fish into the model upstream of the screen, simulating conditions at a turbine inlet. Systematically changing the screen angle, flow velocity, and other variables, the team used a video camera to record fish travel through the model, thus monitoring any contact with the screen. They then collected the fish, evaluated them for scale damage, and held them 72 hours for delayed mortalities.

Results: All species and sizes of fish passed successfully through the system at three screen angles - 10.5, 16.5 and 30 - when test section velocity exceeded 5 fps and bypass velocity exceeded the test section velocity by 20%. Impingement occurred at velocities set below 4 fps. Of the 599 fish that contacted the screen, only two lost scales. There was no delayed mortality.

Dewatering Findings

Satisfactory fish passage resulted when using 10.5, 16.5 and 30 degree angled parallel bar wedgewire screen with appropriate magnitude and ratio of bypass to test section velocities.

Impingement could be predictably produced or avoided with all fish species tested by varying the magnitude and proportion of test section and bypass velocities. Impingement generally occurred when the bypass velocity was less than the test section velocity, especially when the latter was less than 4 fps.

Any possible impingement at the downstream end of the screen can be eliminated by reducing the screen porosity of the last 18 inches of screen length or by increasing the bypass and/or test section velocity.

Parallel bar wedgewire screen manufactured by Johnson and Hendrick screen companies both performed satisfactorily with respect to fish passage. One type of perforated plate received limited evaluation and appeared to perform similarly for fish, but debris accumulation was noticeably greater.

The velocity vector component perpendicular to the screen (Vn) is not a factor of significance with respect to fish passage through a range of approximately 0.5 to 3.0 fps if test section velocities are maintained above 5 fps.

Individuals of all salmonid fish species and lengths tested, passed through the screened model most effectively when water velocity through the conduit was greater than 6 fps and bypass velocity exceeded this by at least 20%.

No 72 hour delayed mortality was observed for any of the fish which passed through the model during various test treatments.

The decreased velocity which occurs within the boundary layer one inch from the test section's top and sides is significant at low test section velocities and explains why most impingement occurs first along the edges of the screen.

References: N/A

PROJECT: USACE, WALLA WALLA DISTRICT DEWATERING SYSTEM FIELD INVESTIGATION **J.O. NO. 05570.04**

NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: 10:00 AM **DATE:** 6/22/95

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	George Heise	**of**	Cal. Dept of Fish and Game	(916) 653-2189
TOPIC:	Use of Perforated Plate in Fish Screens			

DISCUSSION: Johnson asked Heise about his experience with use of perforated plate as a primary screen fabric. Heise said that the California Department of Fish and Game is using 1/8 inch aluminum perforated plate with 5/32 holes on 7/32 centers (staggered). This material has approximately a 46% open area. He said for screens designed to California's fry velocity criteria (0.33 ft/s approach velocity) with an effective cleaner, the perforated plate is as functional (minimal fish impingement with good cleaning) as wedge-wire. He said that the only reason he might prefer wedge-wire is that he perceives wedge-wire to be a flatter material with better quality control. Heise said that if water quality is acceptable, California Fish and Game has found that plate life should be in excess of ten years.

ACTION REQUIRED: None

COPIES TO:
R. Dulin
R. Gelle

Project Task No.
Project File

PROJECT: **USACE, WALLA WALLA DISTRICT DEWATERING SYSTEM FIELD INVESTIGATION** **J.O. NO. 05570.04**

NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: **9:00 AM** **DATE: 6/26/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Steve Rainey	**of**	NMFS	(503) 230-5418
TOPIC:	Use of Perforated Plate in Fish Screens			

DISCUSSION: Johnson asked Rainey about the performance of perforated plate in screen structures designed to the NMFS juvenile fry criteria. Rainey said that they have gone to the more conservative screen opening size criteria based on observations at Dryden where 6 to 7% entrainment was seen using wedge-wire with 1/8 inch slot width. Also studies conducted at a Cowlitz hatchery showed perforated plate with 3/32 openings to perform well. Rainey noted that with a good cleaner, perforated plate should function as well as wedge-wire. He said that he would prefer stainless steel perforated plate and questioned the service life of aluminum. He feels that perforated plate, depending on how installed, can supply as flat and smooth a screen surface as wedge-wire. Rainey noted that he has seen very rough wedge-wire installations. Johnson noted that the perforated plate used with the surface collector at Rocky Reach does not comply with the current NMFS criteria. Rainey noted that the design was developed prior to the release of the current criteria. Rainey said that variances from the current criteria might be allowed if it can be documented that the screens will not encounter fry smaller than 50 mm in

ACTION REQUIRED: None

COPIES TO:
R. Dulin
R. Gelle
Project Task No.
Project File

length. He noted that perforated plate typically has a smaller percentage of open area than wedge-wire. As a consequence, with fouling, head losses will increase more quickly (perforated plate tends to be more sensitive to fouling). He said however that a bigger issue is recognizing the type of debris, and selecting screen materials that handle that debris well.

ACTION REQUIRED: None

COPIES TO:

R. Dulin	Project Task No.
R. Gelle	Project File

PROJECT: **USACE, WALLA WALLA DISTRICT DEWATERING SYSTEM FIELD INVESTIGATION** **J.O. NO. 05570.02**

NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: **10:00 AM** **DATE: 6/16/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Tony Norris	**of**	Portland District COE	(503) 326-6405
TOPIC:	Green Peter Dam Fish Collector Dewatering Facility			

DISCUSSION: Johnson was referred from John Ferguson to Ted Edmister to Tony Norris in pursuing this information (Rock Peters was not available). The Green Peter collector and dewatering facility has been operating since 1967. The dewatering facility reduces a flow of 200 cfs to a bypass flow of approximately 10 cfs. The dewatering facility uses a circular bar screen (bars oriented parallel to the flow) as its primary element. Porosity control is provided with a perforated plate backing. The facility was developed through use of a hydraulic model study. Details on the criteria that the dewatering facility was designed to are not readily available. Norris did not possess operational information including information on the fishery, fish exclusion effectiveness, and cleaning methods and characteristics. Johnson was referred back to Rock Peters for this information. Rock Peters (503) 326-6484 will return to the Portland Office on June 26.

ACTION REQUIRED: None

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Project Task No.
Project File

PROJECT: **USACE, WALLA WALLA DISTRICT DEWATERING SYSTEM FIELD INVESTIGATION** **J.O. NO. 05570.02**

NOTES OF TELEPHONE CONVERSATION

STONE & WEBSTER ENGINEERING CORPORATION

TIME: **9:00 AM** **DATE: 6/12/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Steve Rainey	**of**	NMFS	(503) 230-5418
TOPIC:	Conformation of Fish Screen Design Criteria			

DISCUSSION:

In response to a review comment on the draft Functional Design Criteria, Johnson called Rainey and asked if the Juvenile Screening Criteria Revised February 16, 1995 is current. Rainey said that it was and said that some Corps offices may have not yet received that revised criteria. Rainey said that variances on the criteria have been allowed at some mainstem sites based on thorough fisheries surveys.

ACTION REQUIRED: None

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DEWATERING SYSTEM FIELD
INVESTIGATION

NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: **10:00 AM** **DATE: 5/23/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Ken Bates	**of**	Washington Dept of F & W	(206) 902-2545
TOPIC:	Surface Collector Dewatering Criteria			

DISCUSSION: The State of Washington generally accepts the NMFS juvenile fish screen criteria of February 16, 1995. The state defaults to the fry criteria unless absence of fry and lack of adverse temperature conditions is verified. With respect to high velocity screens, Bates said that the state considers the Eicher/MIS screen concepts as being developmental. Dewatering concepts using high velocity screens would require rigorous development and verification as outlined in the NMFS position paper of January 1995 on experimental technology.

ACTION REQUIRED: None

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PROJECT: USACE, WALLA WALLA DISTRICT DEWATERING SYSTEM FIELD INVESTIGATION — **J.O. NO. 05570.02**

NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: 10:30 AM — **DATE:** 5/22/95

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Steve Pettit	**of**	Idaho Dept. Fish and Game	(208) 799-3475
TOPIC:	Surface Collector Dewatering Criteria.			

DISCUSSION: Pettit confirmed the State of Idaho's support for the NMFS Juvenile Fish Screen Criteria of February 16, 1995. Pettit cautioned that the states and tribes want surface collectors designed with the flexibility that juveniles could be passed either by spill or diverted to a bypass conduit. It is felt that direct passage over the spillways eliminates point source predation and minimizes fish contact with transport structures.

ACTION REQUIRED: None

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TIME: **10:30 AM** **DATE: 5/15/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Hugh Smith	**of**	BC Hydro	(604) 528-7811
TOPIC:	BC Hydro Fish Screening Activities			

DISCUSSION: A two year evaluation of the Puntledge screens is complete. The screens, which were designed for 37 mm Chinook fry have been very effective. Total mortalities (initial plus 96 hour delayed) associated with 80-110 mm Coho passage are less than 0.2 percent. Total mortalities for 28 mm Chum fry were 3.5 percent. The screens operate with a resultant approach velocity of 6.0 ft/s. The screens are back flushed on a four hour cycle. Fish losses associated with back flush are estimated at 1.25 percent. Mortalities associated with turbine passage have been evaluated at 58 percent. The cleaning cycle might be lengthened (fouling generated head losses are small). To minimize potential concern with negative pressure development in the woodstave penstock, the conservative cleaning frequency is being maintained. The screens are cleaned once a year using high pressure spray. Both the penstock and the under side of the screen have been colonized by blackfly larvae. The colonization does not effect head loss. BC Hydro is considering use of modular inclined screens at additional sites. In general out migrant screening and guidance is not a concern in that most of their structures are above the extent of the anadromous runs.

ACTION REQUIRED: None

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TIME: **9:30 AM** **DATE: 5/15/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Berry Chillibeck	**of**	Canadian Department of Fisheries	(604) 666-3765

TOPIC: Canadian Fish Screening Activities

DISCUSSION: Chillibeck said that he is very happy with the performance of the Puntledge Eicher Screens. Efficiencies have been well above 99% with delayed mortalities well below 1% (see the discussion with Hugh Smith for more detail). He said that even though the screen has proven effective, the Department of Fisheries still considers the concept developmental and would require that any new proposed installations be physically model studied. Detailed performance evaluations would also be required. Design criteria for new installations would be tailored to the site specific fishery. He said that he and Chris Katopodis are currently working at development of nation wide design criteria (screening opening size and velocity). The criteria will be species and size specific. Site specific criteria could be developed through use of swimming studies. General criteria will be established based on the conservative envelope of existing data. This criteria will be released to the public by late summer or early fall 1995.

ACTION REQUIRED: None

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NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: **9:00 AM** **DATE: 5/15/95**

FROM:	Perry Johnson	**of**	SWEC	(303) 741-7117
TO:	Chuck Sullivan	**of**	Electric Power Research Institute (EPRI) (415) 855-8948	

TOPIC: Current EPRI Fish Screening Activities

DISCUSSION: Chuck said that current EPRI screening activities are centered around the Green Island Modular Inclined Screen (MIS) installation on the Hudson River NY. This is a collaborative study with Niagara Mohawk Power. The screen module has been fabricated and will be installed in the next few weeks. A shake down and evaluation with resident species will follow. The blueback herring run, which is of particular concern, occurs in October and November. They are hoping for a good run this year to obtain a rigorous evaluation. Chuck said that he had not talked with Hugh Smith (BC Hydro) about Puntledge since August of 1994. At that time BC Hydro was very happy with how the screens were performing.

ACTION REQUIRED: None

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TIME: **11:00 AM** **DATE: May 11, 1995**

FROM:	Steve Townsley	**of**	SWEC	(303) 741-7067
TO:	Mark Summers	**of**	USACE - NPW	(509) 527-7603
TOPIC:	Structural Design Criteria for Surface Collection Structure			

DISCUSSION: Mark is the Lead Structural Engineer for the USACE NPW District design of the surface collection structure which is being designed as a floating structure. I called to inquire about design criteria for their designs.

Mark said they do not have a design criteria document containing the information that I requested which included loading conditions, safety factors, allowable stresses, and design manuals/codes that are being used. He passed on general information over the phone.

The loading conditions are being evaluated individually and in numerous combinations are:

Powerhouse unit startup
Powerhouse unit shutdown (waterhammer)
Wind and wave
Turbine flows

The structural design code being used is the American Institute of Steel Construction (AISC) Manual of Steel Construction using either the Allowable Stress Design (ASD) method or the Load and Resistance Factor Design (LRFD) method. The USACE "Design of Hydraulic Steel Structures, EM-1110-2-2105" is <u>not</u> being used since this is a <u>prototype</u> structure. He said that

the factors in this manual may not be used in the final surface bypass structure design either since the factors were intended to provide for unknowns.

In response to my question, Mark said they were asked to design a floating structure versus a fixed structure. He thought the reasoning for that was to provide room for cleaning the trashracks. He said their design will have horizontal struts mounted to the structure at both high and low points. These struts will connect to some type of rail system mounted on the face of the sloped piers allowing the structure elevation to vary, remain plumb, and remain a set distance from the piers. He said they considered a frame system mounted on the piers with vertical slots for the structure to track in, but the lateral loads appeared too high to handle without lateral bracing between each pier. This lateral bracing would interfere with trashrack cleaning equipment so they selected the strut method instead.

In responsed to my question, Mark said the 60-foot deep structure was a nominal depth and was not intended to be a hydraulic depth. I informed him that Lynn Reese's notes for design criteria list a 60 feet by 20 feet flow area. He said this will not be the case with the structure that they are designing. He thought that the range of flow depths would be from about 54 feet to about 58 feet depending on the actual weight of the system.

I told Mark I would be in touch with him with further questions and that I did not need loading conditions with specific magnitudes at this time.

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NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME: **10:00 AM** **DATE: 5/11/95**

FROM: Perry Johnson **of** SWEC (303) 741-7117

TO: Chris Katopodis **of** Canadian Department of Fisheries and Oceans, Freshwater Institute, Winnipeg Manitoba (204) 983-5181

TOPIC: Recent Canadian Fish Exclusion Experience

DISCUSSION: Chris said that Canada has no standard national screening criteria or performance philosophy. Criteria and accepted screening techniques tend to vary by region. Currently in Eastern Canada louvers are popular. In Western Canada, success with the Eicher screens at Puntledge has generate broad interest in high velocity screens (Eicher and MIS). It appears likely that the Canadian Department of Fisheries and Oceans will accept high velocity screens (specific velocity and screen criteria are not yet defined) as a standard screening technique. Chris said that the Freshwater Institute is currently developing screening guidelines for small deliveries. Following this document, parallel documents for canal structures and for large hydro applications will be prepared. The hydro document should be available in two to three years.

ACTION REQUIRED: Send information on the Rocky Reach and Wanapum prototype surface collectors.

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NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME:	**8:00 AM**		**DATE:**	**4/11/95**
FROM:	Richard Dulin	**of**	SWEC	(303) 741-7568
TO:	Steve Rainey	**of**	NMFS	(503) 230-5418
TOPIC:	Current Fish Screening Design Criteria Applications			

DISCUSSION:

SWEC reviewed the current NMFS Fish Screening Design Criteria and noted that the Criteria would not be met by the use of a Modular Inclined Screen (MIS) or an Eicher Screen. Steve concurred that the current criteria does not address "high velocity" screens because they are considered "developmental". Steve did indicate that the use of a MIS for dewatering applications would be considered, but the Agencies would prefer the use of more traditional screening methods. However, Steve indicated that a MIS may be the optimum configuration due to the large volume of water to be handled.

The method of cleaning the screen was discussed and Steve had serious reservations on inverting the screen to remove debris, since this would allow fish to pass through the system rather than being bypassed. Other methods of cleaning such as air burst, water jets, or brushes could work as well, without the loss of some fish.

ACTION REQUIRED: None

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NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME:	2:00 PM		DATE:	3/6/95
FROM:	Richard Dulin	of	SWEC	(303) 741-7568
TO:	Steve Brown	of	Grant PUD	(509) 754-3541
TOPIC:	Wanapum Surface Flow Bypass System			

DISCUSSION:

SWEC inquired why the Bid Drawings Designs are significantly different than the "Surface Flow Attraction Alternative" December 3, 1993 Draft Report. Steve stated that the concepts developed therein would be too complex to have a working prototype in the river by Spring of 1995. The prototype which is now installed utilized many of the concepts developed in the Draft Report, but focused on what could be done in the available window. By the end of this year, there will be a Performance Test Report on the 1995 operations which will cover both operations and the design concepts. Steve will provide a copy of the a current revision of the 1993 Report for our information.

SWEC has been reviewing the Bid Drawings and noted that there is no automated cleaning system for the dewatering area. Steve indicated that the normal cleaning will be done manually with a brush mounted on a long handle. If required, the blowers can be turned around to backwash the perforated plate.

ACTION REQUIRED: None

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NOTES OF TELEPHONE CONVERSATION
STONE & WEBSTER ENGINEERING CORPORATION

TIME:	**8:00 AM**		**DATE:**	**3/4/95**
FROM:	Richard Dulin	**of**	SWEC	(303) 741-7568
TO:	Steve Rainey	**of**	NMFS	(503) 230-5418
TOPIC:	Current Fish Screening Design Criteria			

DISCUSSION:

SWEC requested of NMFS to provide the current Design Criteria on screening of fry and fingerlings for dewatering systems on all projects. Steve indicated that the criteria which has been in place since 1989 has been recently updated and he will provide a copy of the criteria.

SWEC inquired as to the reasons for the wholesale switching from mesh screens to wedge wire bar screens. Steve indicated that a study was done in California of the performance of mesh screens, perforated plate and wedge wire bar screens. This study concluded that the wedge wire bar screens out performed the other two medium in both self cleaning and produced less damage to the fish. Steve will provide a paper which addresses these issues.

ACTION REQUIRED: None

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